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AAESEE

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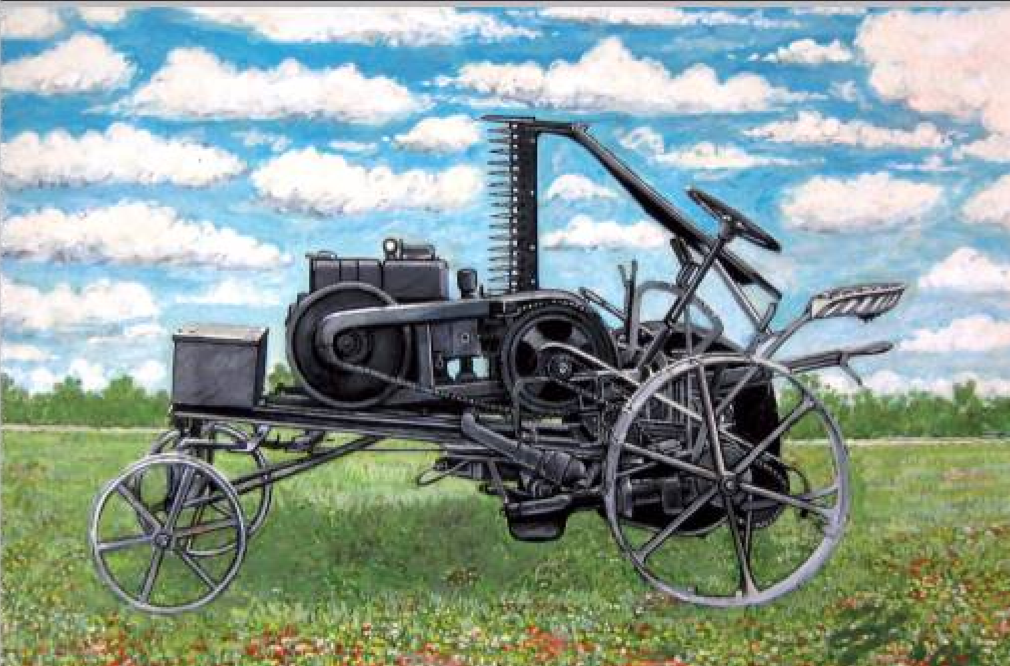
40. INTERNATIONAL SYMPOSIUM ON
AGRICULTURAL ENGINEERING**

Actual Tasks on Agricultural Engineering

OPATIJA, CROATIA, 21. - 24. FEBRUARY 2012



SVEUČILIŠTE U ZAGREBU AGRONOMSKI FAKULTET
ZAVOD ZA MEHANIZACIJU POLJOPRIVREDE
POLJOPRIVREDNI FAKULTET SVEUČILIŠTA U OSIJEKU
UNIVERZA V MARIBORU FAKULTETA ZA KMETIJSTVO IN BIOSISTEMSKE VEDE
KMETIJSKI INŠTITUT SLOVENIJE
MAĐARSKI INSTITUT ZA POLJOPRIVREDNU TEHNIKU
HRVATSKA UDRUGA ZA POLJOPRIVREDNU TEHNIKU

AAESEE

AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

ZBORNIK RADOVA

40. MEĐUNARODNOG SIMPOZIJA IZ PODRUČJA MEHANIZACIJE POLJOPRIVREDE

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PRIČA O TRAKTORU S NASLOVNICE

Fendt Dieselross

Europsku industriju traktora između dva svjetska rata i netom potom karakterizirale su manje izvedbe traktora namijenjene korištenju na manjim gospodarstvima i u industriji. Njemački proizvođači Fendt, Kramer, Deutz i drugi razvili su jednostavne i jeftine modele traktora tako da su stacionarni motor ugradili na jednostavan nosivi okvir – šasiju. Motor su povezali s jednostavnim mjenjačem, dodali spremnik za gorivo, sjedalo za vozača, kotače i sustav za upravljanje i kočenje. Naprednije izvedbe su imale i elektropokretač, te električna svjetla. Hlađenje deutzovog stacionarnog dizel motora (slični motor je proizvodio Torpedo Rijeka od pedesetih godina prošlog stoljeća) bilo je riješeno na najjednostavniji način, sustavom s isparavanjem vode (otvorene izvedbe ili s plovkom za signalizaciju razine vode). Posuda s vodom za hlađenje je bila smještena iznad motora, a voda je okruživala cijeli cilindar motora. Pri atmosferskom tlaku voda se može zagrijati samo do 100 ºC (pri čemu zavrije i isparava. Na taj način cilindar kojeg zagrijavaju plinovi nastali sagorijevanjem goriva ne može se pregrijati obzirom da ga neprekidno okružuje voda. Da bi se spriječilo pregrijavanje i "zaribavanje" motora bilo je potrebno često dolijevati vodu koja se gubila isparavanjem. Motor je bio opremljen velikim zamašnjakom vidljivim na desnoj strani traktora. Na zamašnjaku se nalazila remenica za pogon različitih stacionarnih strojeva poput vršalica, crpki za vodu, pila.

Fendtov traktor *dieselross* je tako bio prvi mali traktor s dizel motorom u Europi. U Fendtu su prvi primjerak (prikazan na slici, u osnovi samokretna motorna kosilica) proizveli 1928. godine u obiteljskoj kovačnici, već stoljećima poznatoj po raznim izuzetno kvalitetnim kovačkim proizvodima. Osnova za proizvodnju njihovog prvog jednostavnog traktora 1930. godine bila je također motorna kosilica s benzinskim motorom od koje se oblikom nije bitno razlikovao. Traktor je bio namijenjen spremanju sijena, obradi tla, transportu i pogonu različitih stacionarnih strojeva čija je primjena tada bila raširena u poljoprivredi. Na jednostavnu željeznu šasiju je dograđen stacionarni deutzov dizel motor snage 6,6 kW (9 KS) sa sustavom hlađenja isparavanjem vode. Od 1936. godine u upotrebi su bili snažniji deutzovi motori od 8,8 kW (12 KS). Prijenos snage s motora na jednostavni mjenjač bi je riješen lančanim prijenosom.

Traktor je primarno bio namijenjen malim njemačkim poljoprivrednim gospodarstvima koja nisu bila u mogućnosti nabavljati veće i konstrukcijski dorađenije strojeve, tada već dostupne na tržištu. Slijedećim modelom *F 18* koji je bio u proizvodnji od 1937. do 1942. godine Fendt se uvrstio među proizvođače koji su traktore proizvodili u većim serijama.

Tekst: Viktor Jejčič   Slika u tehnici gvaša: Dušan Jejčič

PREDGOVOR – PREFACE

Ove godine obilježavamo 40. obljetnicu ideje i truda profesora Zavoda za poljoprivredno strojarstvo, Poljoprivrednog fakulteta Sveučilišta u Zagrebu, koji su davne 1970. u Zagrebu, organizirali prvi međunarodni simpozij ”Aktualni problemi mehanizacije poljoprivrede”. Slijedom njihove zamisli, a uz stalnu potporu kolega iz struke, strukovnih udruga (HUPT i HAD), trgovačkih kuća-predstavnika svjetskih proizvođača poljoprivrednih strojeva i opreme, Ministarstva znanosti obrazovanja i športa i Ministarstva poljoprivrede, šumarstva i vodnog gospodarstva, te međunarodnih udruga Poljoprivredne tehnike (EurAgEng, CIGR, AAAE, AAESEE i ASABE) očuvali smo ovaj, danas svjetski znan skup. Proteklih godina obišli smo gradove, domaćine: Zagreb (’70, ‘82), Zadar (’75, ‘87), Poreč (’77, ‘81), Split (’78, ’85), Opatija (’79, ’83, ’84, ’88, ’90, ’94 – 2012), Šibenik (’80), Rovinj (’86), Trogir (’89), Stubičke toplice (‘92) Pula (’91, ’93). Najdraži grad domaćin s 24 održana skupa je Opatija, istinski biser Jadrana. Ukupan broj radova od 1.699, varirao je od 20 – 83 po skupu, a ukupan broj stranica svih Zbornika je 16.164 s variranjem 58 – 900 po skupu. Ovaj 40. po redu Zbornik sadrži 57 radova sa slijedećim učešćem: Češka Republika (1), Italija, Mađarska (2), Estonija (3), Hrvatska (5), Srbija (8), Slovenija (9), Rumunjska (27). Zahvaljujemo sponzorima, autorima referata, te svim sudionicima. Zahvaljujemo Ministarstvu znanosti i tehnologije Republike Hrvatske na potpori. Posebna hvala našem suizdavaču i tehničkom uredniku mr. sc. Hrvoju Zrnčiću za izuzetnu preciznost i predanost zajedničkom poslu.

This year we celebrate 40th jubilee of an idea and great effort of our predecessors, professors of Agricultural Engineering Department, Faculty of Agriculture, University of Zagreb who 1970. Organized in Zagreb 1st International symposium ”Actual Problems of Agricultural Engineering”. Proceeded their idea with long-term support of our colleagues, our associations (CAES, CSA), commercial representatives of the world famous agricultural machinery and equipment producers, Ministry of sciences, education and sport, Ministry of agriculture, forestry and water management and finally world known associations for agricultural engineering (EurAgEng, CIGR, AAAE, AAESEE and ASABE) we succeeded to preserve this now world known symposium. During all that years host towns were as follows: Zagreb (’70, ‘82), Zadar (’75, ‘87), Poreč (’77, ‘81), Split (’78, ’85), Opatija (’79, ’83, ’84, ’88, ’90, ’94 – ’12), Šibenik (’80), Rovinj (’86), Trogir (’89), Stubičke toplice (‘92) Pula (’91, ’93). So, Opatija, the real pearl of Adriatic coast was our favourite town 24 times. Total number of published papers was 1,699 with variations 20 to 83 per proceedings. Total number of pages was 16,164 with variations of 58 to 900 per proceedings. This proceedings contains 57 papers among them are: Czech Republic (1), Italy and Hungary (2), Estonia (3), Croatia (5), Serbia (8), Slovenia (9) and Romania (27) papers. We would like to thank authors, reviewers, participants and especially sponsors for their contribution to organise the symposium. We especially emphasize sponsoring of Ministry of Sciences and technology of Republic of Croatia who support us for 18 years. Special acknowledgment our co-publisher and technical editor MSc Hrvoje Zrnčić for his extrodinary accuracy and devotion to our common task.

Chief Editor

Prof. dr. sc. Silvio Košutić

Zagreb, siječanj-January 2012.

SADRŽAJ – CONTENTS

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

THE LEGISLATION FOR THE AGRICULTURE AND FORESTRY TRACTORS IN SLOVENIA

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SUMMARY

In the of motor vehicles exist in the EU a lot of legislative acts that is Directives or Regulations of European Union and international UN/ECE Regulations. For this reason there is in Brussels and in Geneve a lot of working parties that prepared these acts for higher traffic safety of all participants in road transport and for lower harmful influence to the environment. This legislation is following the whole life of motor vehicle and therefore it covers all the events with the vehicle. In this article it is written information about the evolution of legislation in the Republic of Slovenia that is the way from the UN/ECE Regulations to the Directives and Regulations of EU as a legal base.

***Key words**: type-approval, UNECE regulations, EU directives, EU regulations*

INTRODUCTION

Agriculture and forestry tractors are likely other road vehicles involved in traffic and work accidents. Those vehicles have a high centre of gravity and therefore the most accidents are with overturning of tractors. The research of the causes for such accidents has been done and it shows us quite a surprising finding. Neither the relief of the country or the landscape on which agriculture and forestry tractors are used, nor the economic development level of the country have almost no influence on number of deaths in accidents with agriculture and forestry tractors. Tractor and driver have the biggest influence on the number of deaths [1], [2].

Based on the written, we could establish that the overturning of tractor is the most frequent reason for an accident with agriculture or forestry tractor in road traffic. In most studies this is the reason number one [3]. For this reason, we could conclude that if we want to make the traffic and the work with such vehicles safer and prevent unnecessary victims we have to act especially on two fields.

In the area of agriculture and forestry tractors we need to assure that these vehicles become safer. A lot of work was already done in the area of conformity assessment of motor vehicles or rules for putting those vehicles on the market, since there are type-approval rules for safety constructions and for driver's safety belts. Furthermore, we need to assure that type-approved safety constructions for protecting driver (safety arcs or cabins) will be fitted also on older tractors that are still in use. This could be assured with the rules for obligatory equipment of such vehicles and with the control at periodical technical inspections or in authorised organisations for examinations of vehicle modifications in conformity assessment procedures. The implementation of rules in case we demand that all tractors have to be equipped also with the type-approved safety belts represents a bigger problem. This is not a problem for new tractors since they are already equipped with them. For older tractors this is hard to assure. Namely, vehicle manufacturers for those tractors did not foresee safety belts and this represents a big obstacle. The two points safety belts, which can be bought, have to be fitted in type-approved anchorages and in such types of tractors this is practically impossible. The only possible and rational solution would be that authorised organisations for examinations of vehicle modifications in conformity assessment procedures perform only the engineering estimation of fitting of the safety belt on a vehicle or on the seat of the tractor.

In case that one state still did not implement the rules of conformity assessment of motor vehicles before putting on the market, it is necessary to ensure safety at least in the area, which proves to be most problematic in terms of deaths. This means that it is necessary to introduce a demand for obligatory equipment of tractors with type-approved safety arcs or cabins and assure that tractors in use will have proper acting breakings. These are the minimum conditions that have the greatest impact on the number of deaths in traffic with such vehicles; of course a step forward would also be the demand for tractor drivers to use of type-approved safety belts.

The second area is the area of drivers. They have to be well educated in order to recognise what is the proper use of these vehicles, where their limits are and how to recognise the moments where they are only one step from causing an accident. This education has to on specific driving conditions, driving with trailers and interchangeable towed machinery, on loading of different loads, fixing the loads, maintaining of tractor, equipment etc.

And last but not least, the supervision is also very important. Tractors that are registered and involved in road traffic are under the supervision of the traffic police. Tractors used by people that work in agriculture are under supervision of the Inspection Service of the Ministry of Labour, Family and Social Affairs or Inspection Service of the Ministry of Agriculture, Forestry and Food. Tractors that are not registered and are used by persons, who are not agricultural workers, are outside the scope of supervision as well as forestry tractors, that are in use mostly in forests and almost never on public roads and are therefore not registered. According to the Directive for agriculture and forestry tractors 74/150/ECE, last amended by the Directive 2003/37/EC, the supervision of all tractors is obligatory. The directive prescribes that only those tractors, that do not endanger the safety of their drivers, passengers and other participants in the traffic or at work, do not damage roads and do not excessively pollute the environment, should be used in road traffic and at agriculture and forestry work. For this reason, it is necessary to set the proper legal bases, so that both inspection services alone or with the help of traffic police could inspect tractors also outside public roads and also if they are not registered. In such cases the intention of such supervision is mainly to ensure the faultlessness of those elements of the tractor, that are important for safety of a driver and also of other participants in the traffic (safety arc or cabin, safety belt, breakings, light equipment).

VEHICLE LEGISLATION

In the area of conformity assessment of motor vehicles we have two parallel systems of legislation:

- EU Directives / Regulations and
- UNECE Regulations.

EU directives and regulations are prepared in Brussels and are valid for all EU Member States. They are prepared by the European Commission – DG ENTERPRISE AND INDUSTRY in its working groups. If we name only some of them:

- TCMV –Technical Committee – Motor Vehicles,
- CATP MV – Committee on the adaptation to technical progress Motor vehicles,
- MVWG – Motor Vehicles Working Group,
- MCWG – Motorcycle Working Group,
- CATP AT – Committee on the adaptation to technical progress Agricultural and forestry tractors,
- WGAT – Working Group on Agricultural Tractors,
- TAAEG – Type-Approval Authorities Expert Group…

The information about the work in those working parties is on web site of DG [6].

The acceptance system can be comittology, when they are accepted only on the level of the European Commission, or co-decision, when they are accepted by the Council of the European Union and in the process of cooperating with the Commission and the European Parliament. In the European legislation for the motor vehicle there are three framework Directives / Regulations (one for motor vehicles with four or more wheels, one for two and three wheelers and for quadricycles, and one for agricultural and forestry tractors). Under each of these frameworks Directive / Regulation are individual Directives / Regulations that regulate certain systems, components and separate technical units of the vehicle. Every EU Member State has an obligation to implement Directives into its national law and also to report this action to the European Commission when they are implemented. On the other side Regulations are automatically applicable in all member states at the same time and only rarely you need to make a national act about it (such as decision, who is responsible for monitoring or reporting to the European Commission).

UNECE Regulations are prepared and accepted in the United Nations in Geneva in the working party called World Forum for Harmonization of Vehicle Regulations (WP.29), and they apply to all countries that are signatories to the agreement (Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles and the conditions for reciprocal recognition of approvals granted on the basis of these prescriptions; so-called Agreement 1958) which is the basis for membership in that group and individual rules. Beside this in this forum global technical regulations (GTR) rules are prepared, which are valid for all signatory countries and among them there are also the USA and China. Legal basis for this is Agreement concerning the establishing of global technical regulations for wheeled vehicles, equipment and parts which can be fitted and/or be used on wheeled vehicles; so-called Agreement 1998. UNECE Regulations are prepared by working groups which were established in areas of work. If we name only some of them:

- Working party on noise (GRB),
- Working party on Lighting and Light-Signalling (GRE),
- Working party on Pollution and Energy (GRPE) ...

The information about the work in those working parties is on web site of UNECE [5].

That means that EU Directives / Regulations and UNECE Regulations in the field of motor vehicles actually cover the same systems, components and separate technical units of the vehicle. Technical requirements and test conditions are very close to each other. Sometimes are the same, sometimes is the EU Directive / Regulation a little bit ahead and sometimes the UNECE regulation is a bit ahead. Therefore recently there had been some changes made. As is known working groups in Geneva are very strong with a lot of experts from the whole world and in Geneva the European Union votes as a collective member, is slowly coming into force EU Regulations that have only part where are some recitals and articles regarding the application dates and in Annexes you could only find the reference directly to UNECE Regulations. This is actually the optimal way for the technical services performing the approval procedures as well as for manufacturers.

In 2006 DG Enterprise and Industry, which is responsible unit for the motor vehicle legislation has prepared a document called CARS 21 - A Competitive Automotive Regulatory System for 21st century. This is a strategic document, which was also published on the web page of the DG mentioned [4] and that gives the knowledge about the guidance for future preparation of legislation to area of motor vehicles. Here are some of the important guidance in the document:

- Simplification of legislation; this principle involves two types of activities. Firstly gradually replacement of EU Directives with UNECE Regulations and the introduction of self-examination and virtual testing. Secondly the replacing of EU Directives with EU Regulations that brings a unique application in all Member States that eliminates the problems at the implementation and also there is no need for the control of the Member States.
- Better legislation; with the better legislation we would improve the effect and lower costs to producers and indirectly also to vehicle owners.

- International harmonization; the international harmonization of regulations would mean the market expansion for vehicle producers.
- Integrated approach to the development of legislation concerning emissions from motor vehicles.
- Increase of traffic safety; this is achieved with the introduction of different safety systems to vehicles (ESC, SBR, BAS, DRL, Isofix, CAS ...).

One of the framework directives is Directive 2007/46/EU of European Parliament and of the Council from 5 September 2007 establishing a general framework for the approval of motor vehicles and their trailers and also for systems, components and independent technical units intended for such vehicles (Framework Directive). It is in fact a legal framework and basis for type-approval and individual approval of new vehicles, their systems, components and independent technical units. In addition it has an application for sale and the start of use of parts and accessories, intended for vehicles. Among important things there are also conditions for the performing of the EU type-approval (vehicles/parts), actions of an individual approval, issuing of COC documents, vehicle recall and authorisation of technical services. It contains also the 21 Annexes with very detailed information and data requirements (technical data, categorization of vehicles, the requirements for EU type-approval, marking, the scope of COC documents, the procedure for assessing the technical services, the list of parts, which can cause serious risks ...). The framework directives for two and three wheelers and for agriculture and forestry tractors are quite similar structured.

Something different and out of basic principles is a rather new EU Regulation No. 661/2009 of the European Parliament and of the Council from 13 July 2009 on applications for approval for the general safety of motor vehicles and their trailers, systems, components and independent technical units, designed for such vehicles, which is in fact between the framework directive and separate directives. This Regulation was published after the project CARS21, therefore it has the elements that has been laid down in project mentioned. It actually eliminates 50 separate directives and prescribed general safety requirements for vehicles of categories M, N and O:

- Requirements for tires (TPMS - control of pressure, grip on wet grounds, rolling resistance, rolling noise),
- Systems for emergency braking (AEBS),
- Systems to maintain the direction of driving (LDWS),
- Systems for Electronic Stability Control (ESC),
- ...

In Slovenia, procedures of conformity assessment of motor vehicles began in 1993. On that time the legal basis was the Standardization Law. On this basis, the Regulation on type-approval of vehicles and Instruction on the procedure of conformity assessment of vehicles were prepared. In addition to these two regulatory acts we put into force over 80 Orders on type-approval for various systems, components and separate technical units of the vehicle, which transposed into national legislation UNECE Regulations. These Orders were quite short, as we translated only some of the technical conditions and everything else was just a reference to the UNECE Regulations. At that time the type-approval authority was the Office of the Republic of Slovenia for Standardization and Metrology at the Ministry of Science and Technology.

In the beginning, the division of responsibilities in this area was quite complicated:

- Ministry of Science and Technology → conformity assessment of vehicles,
- Ministry of Transport → transports,
- Ministry of Agriculture, Forestry and Food → agriculture and forestry tractors,
- Ministry of Internal Affairs → technical inspection, registration of vehicles,
- Ministry of Environment and Spatial Planning → end-of-life of vehicles.

In 2001, after the first twinning project with experts from Sweden and Iceland there was a transfer of conformity assessment of motor vehicles and the area of agriculture and forestry tractors to the Ministry of Transport. At the same time, it also started the preparation of new legislation as preparation activities for the accession to the European Union. There was a new legal basis, which has become an "universal act" called Act on Technical Requirements for Products and Conformity Assessment. Under this law, we have prepared guidelines, which undertook the framework directive:

- Rules on the EU-approval of motor vehicles,
- Rules on the EU-approval of motor vehicles with two or three wheels,
- Rules on EU type-approval of agricultural and forestry tractors,
- Rules on conformity assessment of vehicles (national prescriptions),
- Various rules on parts and equipment of vehicles on a first-aid, the requirements for re-categorization of vehicles, on tinting of on vehicles, on the additional installation of rear-view mirrors on vehicles ...

First draft of the Act on motor vehicles has been prepared during the Twinning project working group. Second step on preparation of the Act on motor vehicles was working in the working group in which were experts from several ministries, technical services, traffic inspectorate, the Chamber of work and the Chamber of Commerce. Together we prepared better text of the Act on motor vehicles. In the same time a decision on dividing of Road Traffic safety Act into 4 separate acts was done. Namely it was decided to prepare four new acts (Act on drivers, Act on road traffic rules, Act on roads and Act on motor vehicles) instead of Road Traffic Safety Act and therefore we had to wait for the other three acts to send them in one package into Slovene Parliament.

The Act on motor vehicles has been published in the Slovene Official Journal No. 106 in December 2010 and it contains only the basic requirements for secondary legislation and it is a new legal framework for more detailed legislation.

The main principles of the new Act on motor vehicles are as follows:

1. System tasks on determining conformity assessment of motor vehicles, their registration and technical inspections are united in the Ministry of Transport. That means that the responsibilities of vehicle registration and technical inspections are shifted from the Ministry of Interior to the Ministry of Transport.

2. All operational tasks are performed by the Agency of the Republic of Slovenia for Traffic Safety - Division of vehicles, which may delegate some of the tasks to other contractors, who must acquire the proper authorization of the Agency:

   Technical Services for:

   - Professional tasks in vehicle type-approval procedures,
   - Professional tasks in the process of type-approval of systems, components and separate technical units and protection equipment,
   - Professional tasks in the process of individual approval of vehicles to the general requirements,
   - Professional tasks in the process of individual approval by the special requirements and
   - Individual approval of modified vehicles.

   Professional organizations for:

   - Identification and assessment of technical condition of vehicles,
   - Regular and special technical inspections of vehicles on special requirements,
   - Periodical technical inspections of vehicles.

3. Traffic Inspectorate of the Ministry of Transport take control on vehicles on the market, vehicle registration procedures, technical inspections of vehicles and on vehicles in use. With this act they got also the legal basis for the use of "mobile" units for roadside inspections.
4. Management and maintenance of databases of vehicles is divided among the Ministry of Transport and type-approval authority.
5. Ministry of Transport manages the following databases:

   - Vehicle registration database,
   - Database on technical roadside inspection of the roadworthiness of vehicles carrying out transport.

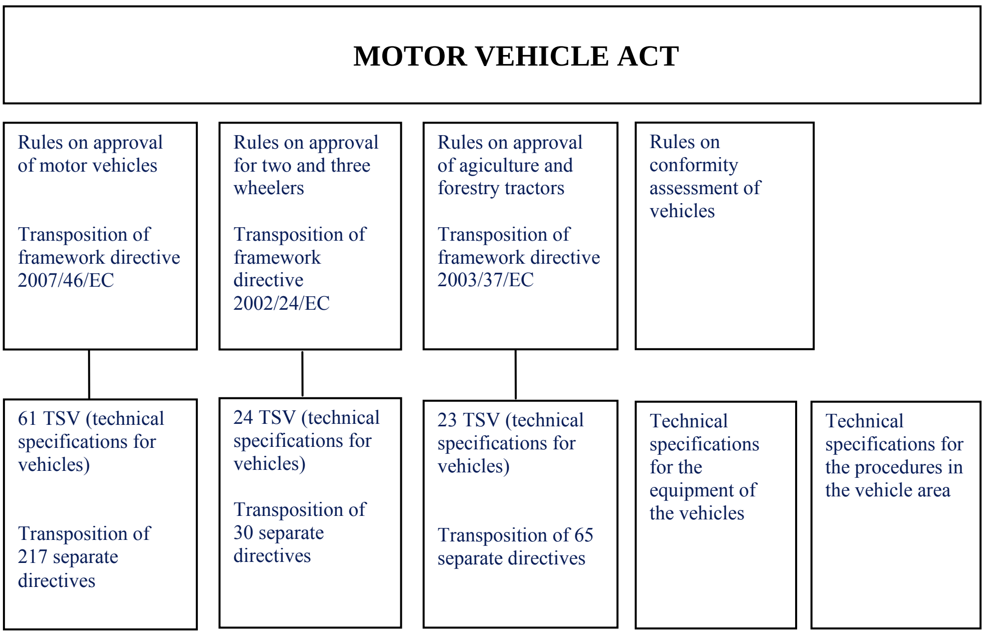
   Type-approval authority manages the following databases:

   - Database on type-approved vehicles,
   - Database on issued certificates of conformity,
   - Database on exams and checking the education of workers who carry out tasks in motor vehicle area and
   - Database on authorisations issued for technical services and professional organizations.

6. Control over agricultural and forestry tractors also outside of public roads. Since each year in Slovenia in accidents with agriculture and forestry tractors suffered up to 20 people this act provides the legal basis for police, inspectors for work and inspectors of Agriculture that can control the tractors on roads and outside of public

roads about the safety equipment of their tractors. The control of agriculture and forestry tractors at work is also a demand from the framework directive.

7. Act introduced the individual approval in Technical Services before re-joining to the road traffic for those vehicles that have been sustained in severe traffic accidents with severe damage of vehicles chassis. This is to attain to be the only transport vehicles that are properly corrected.
8. Due to the Regulation requires EU law sets a mandatory vehicle manufacturers for access to information for the repair and maintenance.



Picture 1 The structure of motor vehicle legislation in Slovenia

Under the Motor vehicle act the Ministry of Transport prepare several rules and orders which are as follows:

1. Rules on approval of motor vehicles,
2. Rules on approval of two and three wheel motor vehicles,
3. Rules on approval of agricultural and forestry tractors,
4. Order on determination of the list of technical specifications for motor vehicles and trailers (with a minimum of four wheels),
5. Order on determination of the list of technical specifications for two and three wheel motor vehicles,

6. Order on determination of the list of technical specifications for agricultural and forestry tractors,
7. Order on determination of the list of technical specifications for the equipment of vehicles,
8. Order on determination of the list of technical specifications for the procedures in the vehicle area,
9. Rules on conformity assessment of vehicles,
10. Rules on devices and equipment of vehicles,
11. Rules on registration of motor vehicles and trailers,
12. Rules on technical inspection of motor vehicles and trailers,
13. Rules on technical roadside inspection of the roadworthiness of vehicles in road traffic,
14. Rules on data collection on vehicles,
15. Rules on the procedures of obtaining authorization to perform the tasks of technical services and professional organizations,
16. Rules on the preparation and issuance of technical specifications for motor vehicles,
17. Rules on education of workers to perform tasks of technical services and professional organizations,
18. Rules on the pricing of printed materials, forms and tables.

CONCLUSION

The area of conformity assessment in the EU is very much regulated because there is in force more than 4000 pages of Regulations and Directives of the European Union and the international UNECE Regulations. Therefore, it is very important to prepare transparent national legislation system that cover the whole area and that all parts of the legislation needed to prevent the people to avoid the system and find a hole in the law. In the next step it is necessary to prepare such system, which could be able to perform all tasks in a sufficient and efficient way. Experts who work in this area must be well trained and have all the necessary equipment. Nevertheless for the good work of the whole system it is important also a good supervising and monitoring system that must function at each point the chain of life of the vehicle. The Slovenian evolution from the old system that based on UNECE Regulations to the new system that is fully harmonised with the European system was quite successful but this procedure takes time. The most difficult task was to shift all activities to the Ministry of Transport because also the old system was working (not perfect) and therefore people were not willing to do this step. Therefore it is also very important to convince ministers to give some "political push" to the better organisational structure.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Review paper

RAZVOJNE TENDENCE TRAKTORSKEGA PARKA V SLOVENIJII

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IZVLEČEK

V Sloveniji je po Popisu kmetijstva iz leta 2010 nekaj več kot 99000 traktorjev. Več kot 50 % kmetijskih gospodarstev ima v Sloveniji le en traktor. Konec leta 2010 je bilo registriranih 89086 traktorjev. V zadnjih letih je značilen trend naraščanja kategorij traktorjev moči med 60 in 80 kW in nad 80 kW moči. Podoben trend je pri traktorjih opazen tudi iz analize Popisa kmetijstva 2010.

***Ključne besede**: število traktorjev, moč traktorjev, novo registrirani traktorji, Slovenija*

UVOD

Kmetijstva danes ni več brez traktorja, ki je glavna in osnovna energetska enota za vleko in pogon različnih kmetijskih priključkov. Kmetijstvo je danes tržna dejavnost, zato lahko večjo konkurenčnost kmetijska gospodarstva povečajo med drugim tudi z uporabo sodobne mehanizacije – traktorjev. V Sloveniji imamo dve pomembni podatkovni bazi o traktorjih. Za prvo skrbi Statistični urad Republike Slovenije (SURS), ki na vsakih 10 let izvede Popis kmetijstva. Druga podatkovna baza pa so podatki Ministrstva za notranje zadeve za registrirana vozila. Poje (2006, 2008, 2010) za Slovenijo ugotavlja, da se je moč novih traktorjev v Sloveniji od leta 1952 do leta 2002 dvignila iz 19,6 na 53,5 kW. Povprečna starost traktorjev v Sloveniji je leta 2002 bila 18,8 let. Ti slovenski traktorji pa v povprečju napravijo na leto 280 delovnih ur ali manj kot eno uro na dan, kar kaže na majhno ekonomsko izraba traktorjev. Pri modernizaciji kmetij in izkoriščanju državnih in evropskih subvencij pa traktor ostaja ena glavnih investicij na kmetiji.

Raziskave glede tehničnega stanja traktorjev, kot pokazatelja razvoja (stanja) kmetijstva opravljajo tako v evropskih državah kot tudi drugje po svetu. Grgić (2009) za Hrvaško ugotavlja, da je zlasti na družinskih kmetijah mehanizacija zelo stara in velikokrat nefunkcionalna. V Avstriji (Schrottmaier in Handler, 2001) ugotavljata porast zmogljivejših traktorjev zaradi večje velikosti kmetijskih gospodarstev. Na Madžarskem je bilo na primer leta 2005 vseh traktorjev 120475, od tega jih je 80 % v lasti privatnih gospodarstev (Hajdu J, Mago L. 2008). Mago (2007) ugotavlja, da je madžarsko kmetijstvo pred resnimi izzivi, ki jih lahko reši tudi z ustreznejšo (efektivnejšo) mehanizacijo, problematične pa so zlasti manjše kmetije.

Namen prispevka je analiza razvojnih tendenc traktorskega parka v Sloveniji tako na osnovi podatkov iz Popisa kmetijstva kot tudi na osnovi podatkov o novo registriranih traktorjih.

METODIKA

Kot vir podatkov za analizo smo uporabili podatkovno bazo Ministrstva za notranje zadeve RS o registriranih vozilih (traktorjih) in podatke Statističnega urada Republike Slovenije in njenega Popisa kmetijstva 2010. V prispevku analiziramo vse traktorje in nove traktorje v izbranih letih. V analizo zajeti podatki so obdelani z ustreznimi statističnimi analizami (opisna statistika).

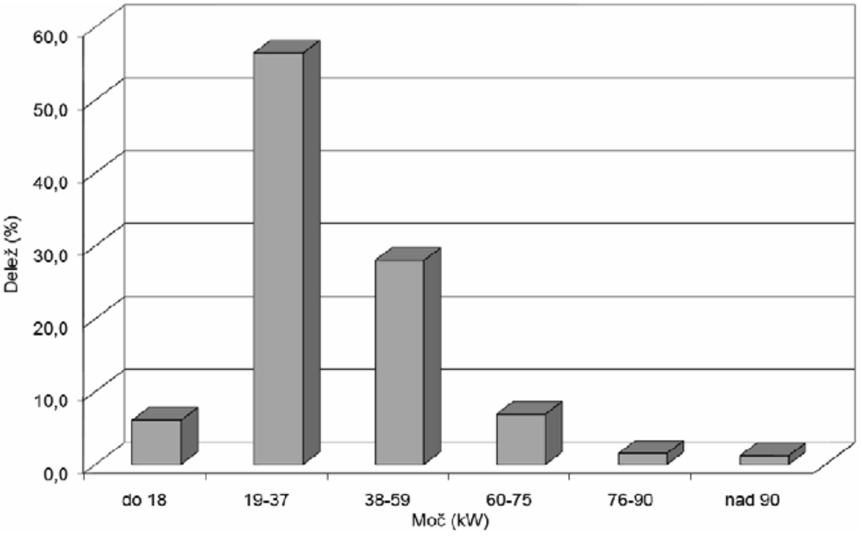
REZULTATI IN DISKUSIJA

Po podatkih iz Popisa kmetijstva, ki ga je leta 2010 napravil Statistični urad RS je bilo takrat v Sloveniji nekaj več kot 99 tisoč traktorjev. Prejšnji Popis kmetijstva iz leta 2000 pa je tedaj naštel dobrih 108 tisoč traktorjev. Nekateri slovenski strokovnjaki trdijo, da je v Sloveniji traktorjev celo več, nekje do 120 ali celo do 130 tisoč traktorjev.

Tabela 1 Število dvoosnih traktorjev v Sloveniji po velikostnih razredih glede na moč traktorjev

Kategorija moči traktorja	Leto		Indeksi 2010/2000
	2000	2010	
do 18 kW	11.928	6.026	50,5%
19-37 kW	69.094	56.235	81,4%
38-59 kW	24.425	27.877	114,1%
60-75 kW	2.045	6.844	334,7%
76-90 kW	386	1.513	392,0%
nad 90 kW	288	1.178	409,0%
Skupaj	108.166	99.673	92,1%

Analiza tabele 1 in grafa 1 nam kaže izredno velik porast števila traktorjev v kategorijah traktorjev nad 60 kW v obdobju med letom 2000 in 2010. Število traktorjev v kategoriji nad 90 kW je celo več kot 4 x večje v letu 2010 kot v letu 2000. Kljub temu da kategorije traktorjev z močjo nad 60 kW od enega do drugega Popisa naraščajo, pa je delež teh traktorjev v celotnem traktorskem parku v Sloveniji tudi v letu 2010 pod 10 % ali bolj natančno 9,6 %.

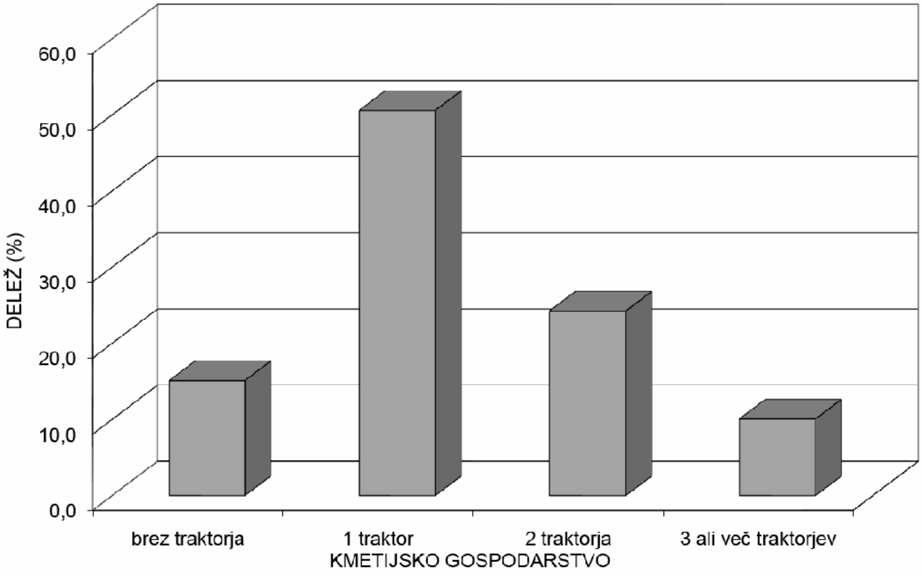


Graf 1 Delež traktorjev v odstotkih po kategorijah moči traktorskega motorja glede na Popis kmetijstva 2010

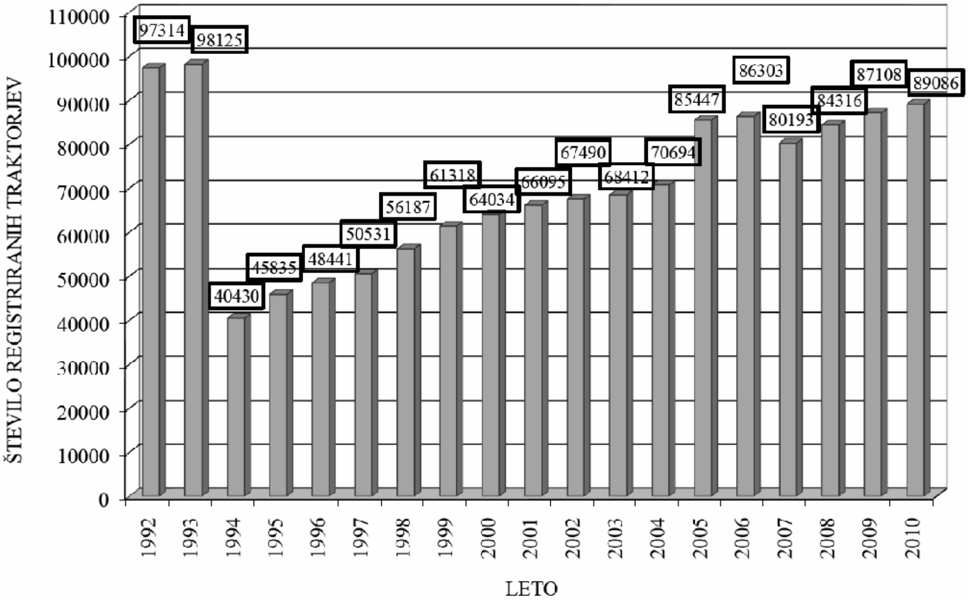
Tabela 2 Število kmetijskih gospodarstev (KG) glede na skupno število traktorjev v Sloveniji

	Število KG		Indeksi 2010/2000	Število traktorjev		Indeksi 2010/2000
	2000	2010		2000	2010	
KG brez dvoosnega traktorja	12.309	11.289	91,7 %	-	-	-
KG z 1 traktorjem	48.048	37.792	78,7%	48.048	37.792	78,7%
KG z 2 traktorjema	20.399	18.111	88,8%	40.798	36.222	88,8%
KG s 3 ali več traktorji	5.711	7.519	131,7%	19.320	25.659	132,8 %
Skupaj	86.467	74.711	86,4%	108.166	99.673	92,1%

Analiza števila traktorjev na posamezno kmetijsko gospodarstvo (tabela 2 in graf 2) pa v Sloveniji med obema Popisoma kmetijstva (2000 in 2010) kaže na zmanjšanje števila kmetijskih gospodarstev za 13,6 %, kakor tudi zmanjšanje števila traktorjev zajetih v Popis kmetijstva za 7,9 %. Manjša se število kmetijskih gospodarstev z enim ali dvema traktorjema. Za 32,8 % pa je poraslo število traktorjev na kmetijskih gospodarstvih s tremi ali več traktorji. Več kot 50 % kmetijskih gospodarstev ima 1 traktor na gospodarstvo, brez traktorja pa je dobrih 15 % kmetijskih gospodarstev. Dva traktorja na kmetijsko gospodarstvo ima po Popisu kmetijstva 2010 24,2 % kmetijskih gospodarstev. Samo 10,1 % kmetijskih gospodarstev pa ima tri ali več traktorjev.



Graf 2 Delež kmetijskih gospodarstev v odstotkih glede na število traktorjev

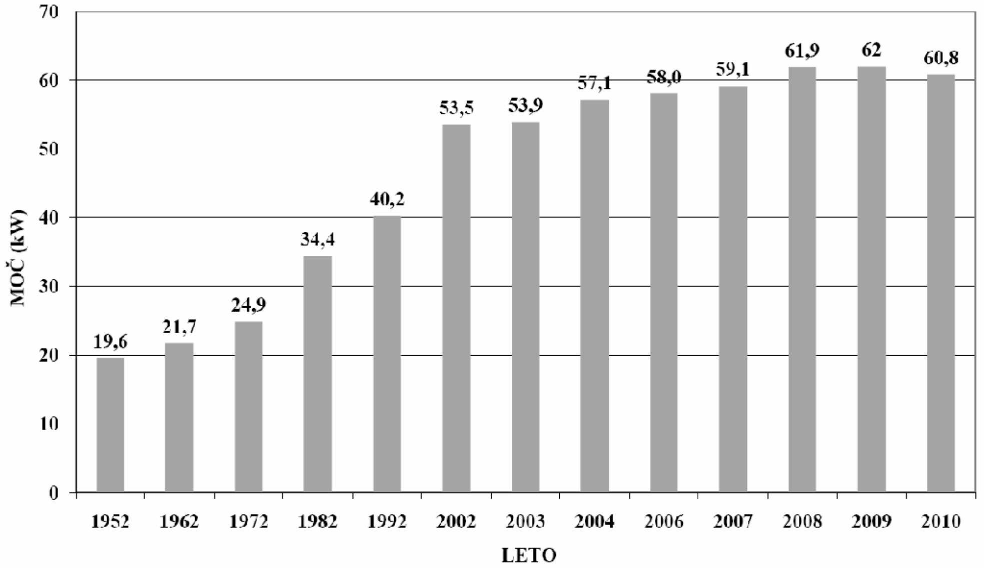


Graf 3 Registrirani traktorji u Sloveniji po letih

Ministrstvo za notranje zadeva ima podatkovno bazo o vseh registriranih vozilih v Sloveniji. V okviru te baze so zajeti vse registrirani traktorji v Sloveniji. To je dejansko tudi največja podatkovna baza o traktorji v Sloveniji.

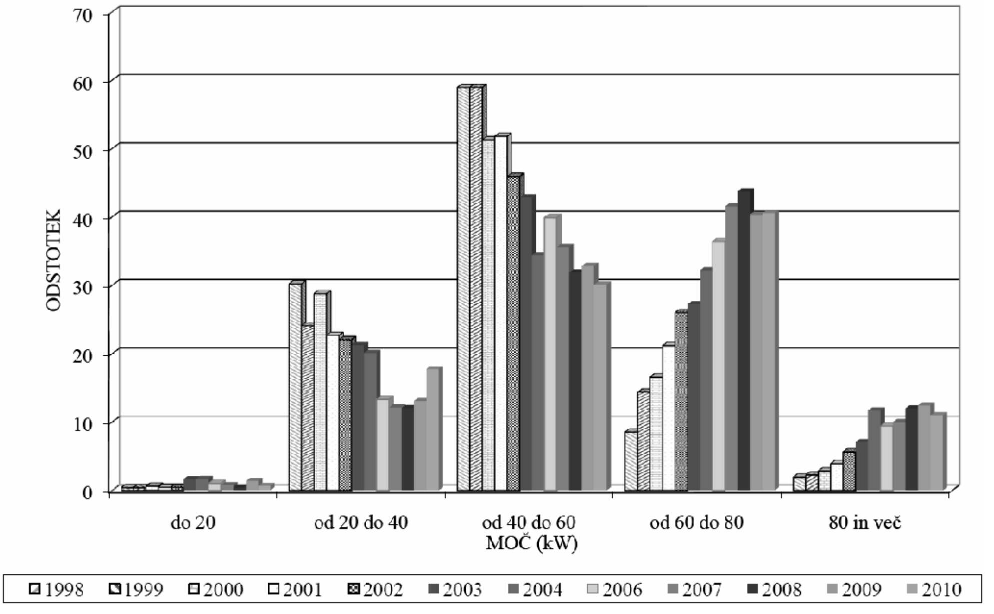
V grafu 3 je prikazano število vseh registriranih traktorjev v Sloveniji za obdobje od leta 1992. V letu 1993 je bilo registriranih 98125 traktorjev, naslednje leto pa se je število registriranih traktorjev zmanjšalo na 40430 traktorjev zaradi prehoda na nove slovenske registrske tablice in takrat marsikdo ni več registriral traktorja. Po tem letu je število registriranih traktorjev počasi naraščalo, velik porast registriranih traktorjev pa je bil v letu 2005 ko je bilo v Sloveniji možno registrirati star traktor tudi brez podatkov o lastništvu. Konec leta 2010 je bilo registrirani 89086 traktorjev.

Iz podatkov Ministrstva za notranje zadev RS smo izračunali tudi povprečno moč registriranih traktorjev za posamezna leta. Iz grafa 4 je razvidno, kako se je povečevala moč po desetletjih in v nekaj zadnjih letih. Za traktorje izdelane in registrirane v letu 1952 je bila izračunana povprečna moč 19,6 kW. V letu 2010 je bila povprečna moč novih traktorjev v Sloveniji 60,8 kW.



Graf 4 Porast moči traktorskih motorjev v Sloveniji v obdobju od 1952 do 2010

Graf 5 prikazuje prvič registrirane traktorje (nove traktorje) v Sloveniji za zadnja leta. Razporejeni so po kategorijah moči, ne glede na proizvajalca ali državo porekla. Iz grafa je razvidno, da v zadnjih letih raste kategorija traktorjev z močjo motorja med 60 in 80 kW ter kategorija nad 80 kW. Kategoriji novih traktorjev z močjo med 30 in 40 kW ter med 40 in 60 kW upadata. Kljub trendu upadanja pa imajo v absolutnem številu še vedno veliko število traktorjev. Odstotek novih traktorjev v Sloveniji z močjo motorja pod 20 kW je majhen in relativno konstanten.



Graf 5 Novi traktorji registrirani v Sloveniji za zadnja leta po različnih kategorijah moči

ZAKLJUČEK

V Sloveniji je po Popisu kmetijstva v letu 2010 bilo dobrih 99 tisoč traktorjev. Od tega je bilo konec istega leta registriranih 89086 traktorjev. Tako Popis kmetijstva kot baza novih registriranih traktorjev kaže na trend naraščanja kategorij traktorjev z močjo nad 60 kW. V letu 2010 je bila povprečna moč novih traktorjev v Sloveniji 60,8 kW. Več kot 50 % kmetijskih gospodarstev ima v Sloveniji le en traktor. Dva traktorja na kmetijsko gospodarstvo ima po Popisu kmetijstva 2010 24,2 % kmetijskih gospodarstev. Samo 10,1 % kmetijskih gospodarstev pa ima tri ali več traktorjev. Iz proizvodno tehničnega vidika je potrebna večja modernizacija slovenskega traktorskega parka.

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THE DEVELOPMENT TRENDS OF THE FLEET OF TRACTORS IN SLOVENIA

SUMMARY

The Agricultural Census of Slovenia from 2010 contains more than 99000 tractors. More than 50 % of agricultural holdings have only one tractor in Slovenia. At the end of 2010 the number of registered tractors was 89086. In the recent years the characteristic increasing trend of new registered tractors categories between 60 and 80 kW and above 80 kW engine power was observed; that was also shown in the Agricultural Census of Slovenia from 2010.

***Key words**: number of tractors, power of tractor, new registered tractors, Slovenia*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.17
Prethodno priopćenje
Preliminary communication

ACTUAL TASKS OF THE TECHNICAL DEVELOPMENT IN AGRICULTURE

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SUMMARY

The current situation of the Hungarian agriculture significantly differs from its previous characteristics before the transition. Historical changes took place in the sector that has modified the possibilities of agricultural technical development in many areas. It is a fact that on the basis of relatively permanent ecological conditions the outputs of agricultural production have dramatically decreased during the last twenty years. According to this, the international competitiveness of the Hungarian agriculture broke down and today the question arises regarding how the Hungarian agriculture could compete with the foreign companies.

The technical development in agriculture is the „fishbone" of complex development activities. It originates from the fact that the technical development in agriculture covers and integrates the biological, chemical and technical factors. In addition to that we have to calculate with the ecological conditions and the tasks of human resources management on the micro level. These factors are strengthened by the effects of the social-political-economic surroundings.

This paper covers the actual possibilities of the agricultural development based on the current Hungarian agro-economic characteristics. On the basis of international sources we can say that the situation is similar in the former socialist countries that emphasises the actuality of this paper even more.

Key words: *agricultural development, agricultural technical development, complexity in agricultural technical development*

INTRODUCTION

Agriculture has a long tradition in most of the Central and Eastern European countries. Due to the excellent ecological characteristics, agriculture has always been of high importance in Hungary. The importance of the sector comes from the food supply of the population, the production of industrial raw materials and the employment possibilities. The sector is historically of high importance in rural development, therefore the agricultural development should be an evergreen, never ending project.

This paper analyses one of the main components of development: the complex technical development that includes some theoretical as well as practical issues and its actual tasks. The topic is relevant not only for Hungary, but to all the ex-socialist countries in the region.

METHOD

The method of the paper is based on the elements of the scientific literature, the results of previous researches and our professional experience.

RESULTS AND DISCUSSION

Some characteristics of the Hungarian agriculture as the background of technical development

The Hungarian agriculture has been influenced by two major national political issues in the last two decades:

- the change of the previous regime took place in 1989, as a result of which the ownership and size structure of the sector have significantly changed, and
- Hungary has joined the EU in 1st May 2004 that brought new elements and directives to the sector in many areas of the regulation.

Table 1 shows how these changes have deeply affected the agricultural sector in Hungary:

Table 1 The importance of the Hungarian agriculture in the national economy

Year	AG as % of total at work	AG as % of GDP	AG as % of investment
1995	8.0	6.8	2.9
2000	6.6	4.6	4.7
2005	5.0	3.6	4.5
2010	4.5	2.9	4.8

Source: HSO (Hungarian Statistical Office)

The data shows that the importance of the Hungarian agriculture in the national economy continuously decreases in the given period. The most significant change is the decrease of its share from the GDP. In order to understand the whole picture and the share of agriculture (2.9%) of the total investments in 1995, it is important to know that this ratio was 15-20% before the change of the regime.

In 2010, only 4.5% of the employed population is in the agricultural sector, which ratio was around 17-18% before the change of the regime.

The most obvious change the table shows is the high increase in the number of farms. Before the regime change there were only 120 state farms (with an average size of 7 000 ha), 1 320 collective farms (with an average size of 3 200 ha), while now there are almost 1 700 thousand agricultural farmers out of which the number of private farms are 570 thousand including 200 thousand farmers who intend to make their living from the sector. The number of joint enterprises is around 13500.

Table 2 Share of Hungarian farms by size of farm and agricultural area

Hectares (ha)	Number of farms	Agricultural area
	Share (%)	
Under 1.0	72.8	1.9
1.1 – 10.0	18.9	8.4
10.1 – 100.0	7.0	25.7
Above 100.1	1.3	64.0
Total	100.0	100.0

Source: HSO (Hungarian Statistical Office)

The agricultural area is less than 1 hectare for 72.8% of the farms that use 1.9% of the total agricultural area available in Hungary. The agricultural area is more than 100 hectare for 1.3% of the farms occupying 2/3 of the total land available. The average size of the joint ventures is 368 ha, while that of the private farmers is 28.4 ha. In the aspect of agricultural development, the available capital of the farms is of high importance as well as how the farms are equipped. It is easy to see that the developmental possibilities of an enterprise with strong capital are much better.

Table 3 Characteristics of the equipment supply

Total Assets Value (1000 HUF/ha)	2001	2006	2010
Small	510	908	1183
Medium	481	715	786
Big	370	600	782
Fixed Assets Value (1000 Ft/ha)			
Small	335	640	816
Medium	298	494	530
Big	161	310	422
Net Investments (1000 HUF/ha)			
Small	8	- 28	- 13
Medium	36	-9	- 1
Big	20	5	- 21

Source: Hungarian FADN

Table 3 shows the equipment supply of the Hungarian farms with different sizes. The analysis is based on the measure units (EUME) used in the EU when ranking the farms. According to this: Small: 2 – 8 EUME, Medium: 8 – 100 EUME, Big: above 100 EUME. EUME: European Measurement Unit (1 EUME = 1200 Euro Standard Gross Margin; Gross Margin = Production Value – Variable Costs). The data applies to the Hungarian test farms.

In the aspect of technical development the value of total assets that shows an increasing tendency in all the three categories is of high importance, however the picture is slightly modified by the high inflation. The most obvious issue related to the lack of capital is the decrease in investment.

Table 4 Characteristics of agricultural employment

Human Work Unit (1/100 ha)	2001	2006	2010
Small	6.4	7.1	6.4
Medium	3.2	3.1	2.8
Big	3.9	3.2	2.9

Source: Hungarian FADN

Development approach

„Development" is a common word, but it has various meanings. In relation to agriculture „development" can be explained best as one among a range of words including „change", „growth", „progress", „advance", „modernisation" and „reconstruction".

The most useful definition of development of agriculture is changes in the biological, chemical, technical, human and farm-economic sub-systems of agriculture and in their relations with the socio-economic system, which are of more than short duration and have more than short-term consequences, and the process that affect these changes or determine their consequences.

Thus some of the changes may prove favourable and some others unfavourable. Some of them may determine now, while others only years later. Some may be fostered or imposed from outside agriculture. Some of them may be natural, rather than the direct result of human decisions. Particular social groups in or outside agriculture may play particular roles in bringing about change. Different groups may be affected differently. The changes may be accelerated or slowed down, or halted.

The definition can be used in all countries, and does not depend on any ideas of „under-development" or poverty. The definition requires logically that those who approve some particular development should state criteria by which they judge.

It is clear that agricultural development, spurred in part by education, the adoption of new technologies, and institutional improvements, can help stimulate broad-based economic development.

Agricultural development can potentially provide a direct increase in rural welfare.

When agricultural development has not been associated with concurrent concern for employment, this development has stimulated less overall economic development than would be possible. Agricultural development has sometimes led to reduced food imports and growing food stocks even though people remain hungry. Mellor (in Norton, Alwang, 1993) has called for an employment-oriented strategy which stresses research, education, rural infrastructure and, most important low-capital intensity industries. A rural sector with growing income can provide a large domestic market for locally produced non-agricultural goods and services.

The logical development strategy for a particular country depends on the available resources, stage of development, and institutional structure of the country.

(Norton, Alwang, 1993)

The following guidelines are elements in an alternative approach to development. They form a perspective strategy aimed at building environmental considerations into development planning.

1. A positive view of the environment needs to be developed, on the basis of present and future livelihood creation: job, incomes and cost-savings. This means a shift towards emphasising the advantages of better environmental practises, including incentives.
2. There is a need to develop labour and time-saving technology for energy, fuel, wood, water, food preparation and post-harvest storage activities.
3. Wherever possible farm grown inputs should be substituted for market purchases, which make additional calls on scarce finance. This will reduce the external dependence of agricultural producers.
4. Non-farm sources of income need to be considered together with the measures needed to make farming systems more sustainable. In practice poor household will not employ more sustainable practises if they perceive them as at the cost of income-generation. In some cases efforts at income supplementation may prevent more sustainable practices from being adopted.
5. Improved livelihood security is required, involving such essential features as land tenure rights and access to common property resources. If extended access to „commons" is leading to increased degradation, other means of bolstering the household's livelihood need to be given emphasis, to provide the essential income supplementation.
6. Government policies should be directed towards plugging gaps in the food system of critical importance to poor people in low resources areas: for example, post-harvest technology and storage, agro forestry, decentralised marketing, improved transport, better biomass utilisation and alternative sources of income generation. Plugging the „agricultural technology" gap means sharing skills and knowledge in the implementation and adaptation of technology as well as developing appropriate technology.
7. Poor people's calculations are based on what they know and what they can anticipate. Better environmental monitoring and forecasting are therefore necessary, and the resulting information and predictions should be much more widely disseminated.

The countries in the world can be divided into two major groups; industrialised and developing ones. In the development of agriculture in the industrialised countries, the forces favour specialisation. In most developing countries the respective conditions are the opposite of those in the industrialised countries. Hungary can be placed somewhere between the two, in my opinion. (Table 5)

Table 5 Conditions for agricultural development: differences between industrialised and developing countries

Criteria	Industrialised (RICH) countries	Hungary	Developing (POOR) countries
Climate-related production risk	lower	lower	higher
Potential negative impact of mechanisation on environment	lower	medium	higher
Population growth	slow	decreasing	rapid
Proportion of population employed in agricultural sector	decreasing	decreasing	constant
Transport and market structure	good	medium	poor
Degree of market involvement	higher	medium	lower
Purchasing power and availability of external inputs	higher	medium	lower
Specialisation and labour productivity	higher	higher	lowe

(Source: Based on J Kotschi et al, 1989)

The Hungarian agriculture similarly to the ones in the other „former socialist" countries underwent/goes basic changes in the early nineties. The earlier formed structural features have been blown up and the transformation has shaken the agriculture as a whole. The participants orientate and move more uncertainly among the new markets comparing with the previous system.

The large-scale state farms and co-operatives totally closed down or were basically transformed. During the transformation the private ownership and the small-scale farms had a priority.

Some elements of the complex technical development, as a phase of agricultural innovation

The model about the *substance of technical development* (Figure 1) shows that technical development serving agricultural production has got a particular bridging role between the production and the previous innovation phases by integrating several factors at the same time. It is important that the marked biological, chemical, human and ecological factors should be in harmony, because otherwise the balance breaks effective factor being in relative minimum as per the minimum-law.

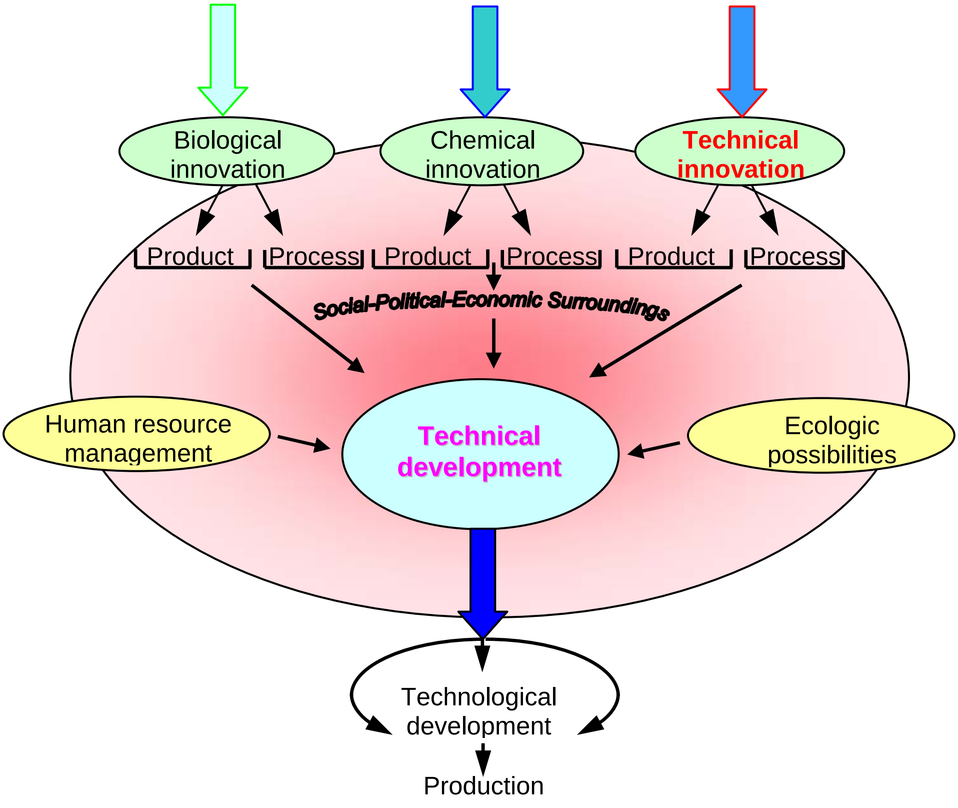

Figure 1 The role and elements of the agricultural technical development
(Source: Husti, 2006)

The main source of the agricultural production development is the technical and technological development. This system of activity is the aggregation of continuous, complex and consistent activities, which have an impact on the elements of the agricultural production (soil, labour and capital goods) causing quantity and quality changes. By this, the production reaches a higher level and in favourable cases it becomes more efficient. The technical development has a number of economical functions besides the modernization of production.

In order to help to understand the definition we have created the "matrix model" of the agricultural technical development. The model in the matrix expresses the relationship between the basic elements of the agricultural production and the effective factors of technical development. (Figure 2)

Based on the model an organization can specify its technical development tasks at a point where a given row meets a given column. The matrix model cannot be considered statically, it is easy to adjust it to the given external and internal circumstances and to the changes of these circumstances in two dimensions (time and space).

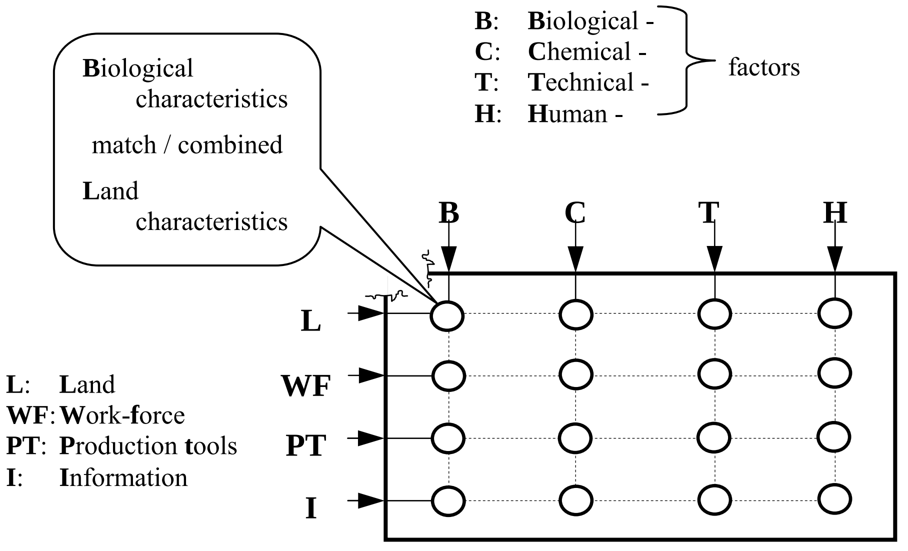

Figure 2 The simplified "combination-matrix-model" of the agricultural technical development (Source: Husti, 2002)

In connection with the agricultural technical development it is obvious that during the production development the ecological conditions (opportunities and given) cannot be ignored. On one hand these can be the conditions of production development on the other hand these can restrict it as well. The agricultural technical development has to ensure that it makes the best of the ecological opportunities and that it avoids the disadvantageous effects. This question is complicated by the fact that part of the ecological factors (above all the climatic circumstances) can hardly or not at all be influenced by humans. That is why it is important to focus on those factors that can be positively influenced by human intervention.

From this list we can highlight the soil which we consider the essential element of production. It is known that Hungary's land features and the shape of their surfaces are different in respect of the agricultural production and its automatisation. The physical-chemical composition of land, its structure and the way it can be cultivated can differ in landscapes plants regardless of administrative, plant or natural borders. The same differences can arise in respect of the surface of the land. If we consider these as objective givens we can see that the effective factors of the technological development are partially applicable considering the ecological givens and opportunities. Based on our experience the features of land and its surface influence the applicable output of machines, the speed, the width of the work area etc. We can also see that the composition of soil has an effect on how the machine should be used and how safe the machine is, how long it can be used and the deterioration period.

In connection with the effective factors of technological development it is necessary to analyze the role and importance of complexity. Some practical examples prove that if the harmonization of development factors fails the expected advantages and ambitions cannot be realized. During the technical development, the effective factors need to be harmonized otherwise as a result of the 'minimum law' the final result of development will be limited by that factor from, which is at the lowest level. One of the most important tasks of the technological development embedded in the innovation process is to provide an integration function between the factors mentioned above. Within the frameworks of this we have to ensure that the effective factors are optimised and that there is harmony between the development factors in time and space.

Actual tasks of technical development in agriculture

The technical development of agriculture is a multi-component, complex task with the biological, chemical and technical factors playing a significant role. In all the three areas, the pressure from the supply market is strong which means that the farmers have to decide which element is the best to be chosen. When making the decision, the ecological factors and the characteristics of human resources should be taken into consideration.

- The biological factors should always match the local characteristics. Using GMO-s could have a special significance. Currently Hungary is determined to avoid GMO-s as a result of which the Hungarian farmers can only choose from the traditional options. In this case the potential productiveness, the resistance and other biological characteristics of the species should be taken into consideration as well. The home-made mother spawns might be cheaper, however their biological values and production security is usually weaker.
- When choosing the chemical factors, the environmental and health care aspects are of high importance. It is not easy to find effective and approved drugs for plant protection and animal care whilst food quality regulations are getting stricter and stricter. The ecological aspects should also be considered in this step. Since most of today's drugs are effective in small doses, having the appropriate equipment for the chosen drug to be applied is especially important in the area of plant protection.
- There is a wide supply in the area of technical factors. It is not exaggeration to say that today there is equipment available to serve every steps of agricultural operation. However, the work quality and ecological aspects of the available machines are not indifferent. It is also important to see how the equipment fits into the whole machine system of a farm. Based on this, the universality, the scale of leverage and other characteristics of any given equipment could be important.

When we talk about the actual tasks of agricultural technical development, we mention the classical development principals. There is no new circumstance that would guide those with a previous systematic development into a new direction. What differs from the previous status however is the dynamism on the supply side. Today a new solution, material or equipment appears on the market much faster than it used to. This fast pace brings new challenges to the farmers and puts the importance of professional knowledge forward. In order to be able to choose between the offers of producers and distributers using aggressive marketing, it is essential that one has an up-to-date professional knowledge of a high level. This circumstance appreciates the role of knowledge and makes it one of the deciding criteria of success related to agricultural development.

Among the factors of agricultural technical development:

- the ecological factors can be considered constant
- the biological, chemical and technical factors are characterized by a dynamic change and a strong supply position
- the professional knowledge related to human factors appreciates, so that the best combination of inputs are found, the one that fits the ecological factors the best and in the most effective way

When defining the actual micro-level tasks of agricultural technical development the economical possibilities and developmental ambitions of a given organization should be taken into consideration as well as the effects coming from the social-political-economic environment. In this matter, there are differences between the practices of the ex-socialist countries. The detailed explanation for that is not the topic of the current thesis because of its content limitations.

CONCLUSIONS

- In the paper, we first determined the main areas and issues of agricultural development based on the current characteristics of the Hungarian agriculture.
- The Hungarian characteristics illustrate well the main issues the ex-socialist countries are facing. We can say that the national role of the agricultural sector is more or less traditionally of high importance. This circumstance justifies that the issues of agricultural development should continuously be taken into consideration.
- The changes of the 1990's have changed the ownership and size structures in agriculture. During the alteration of the previous structure, the privately owned, small size enterprises became dominant with poor capital and development sources. This circumstance has essentially influenced the possibilities and activities in the area of development.
- The agricultural development is a complex task including biological, chemical and technical elements. The aims, ecological characteristics and financial resources of the enterprise should be taken into consideration when defining these elements. The professional knowledge of human resources is of high importance as well since it provides the optimal combination of these factors.
- The development is also influenced by the social, political and economic factors. In this matter, the ex-socialist countries have different practices.
- One of the biggest challenges for the ex-socialist countries in the 21st century is to provide their population with quality food at an affordable price. This can only be achieved by proper agricultural development. This thesis is to provide ideas and solutions for further discussions.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THE ECONOMETRIC ANALYSIS OF THE INNOVATION ACTIVITIES OF THE HUNGARIAN AGRICULTURAL MACHINERY PRODUCERS

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SUMMARY

The current production of the Hungarian agricultural machinery manufacturing sector lags behind the production of the previous years to a great extent. The industry underwent significant changes in the past twenty years primarily with regards to its ownership structure. The new owners do not pay enough money and attention on innovation yet relative to several other international agricultural machinery producers. Due to lack of development, the Hungarian producers have lost their former roles on the Hungarian market (too). A bit more than one-quarter (26-27 percent) of the current total domestic market turnover derives from domestic manufacturers. The extent of market loss and the general situation of the Hungarian agricultural machinery manufacturers justify that the present of this sector and within it he role of innovation must be dealt with by searching the ways-out of the crisis and make steps for development.

The conclusions of our paper are based on the examination results of questionnaires and in-depth interviews that were carried out at 35 Hungarian agricultural machinery manufacturing companies. The characteristic features of the companies that were involved in the examination reflect the situation of the entire sector in Hungary properly. According to our experience and sources, the Hungarian conditions are also applicable and typical of the agricultural machinery production of the other ex-Socialist countries.

In our paper first of all the method of the empirical research is presented where the structure of the questionnaire used in the research and the process of data recording and processing are shown in details. In our present study some of our results together with those based on unvaried descriptive statistics are published. Besides the brand-new or highly developed products and technological (procedure) innovations, novelties in organisation and marketing are also paid *attention. Furthermore, some of the indicators of the innovation performance of the companies are also presented. The question of cooperation between the organisations taking part in innovation is referred to, as well. Taking the challenges of the future into account, the results as hindering or success factors of innovation activities are also organised into a system.*

Key words: *innovation, agro-technical development, key-factors of innovations*

INTRODUCTION

The current production of the Hungarian agricultural machinery manufacturing sector, which used to see better days, lags behind the production of the previous years to a great extent. The organisational structure of the Hungarian agricultural machinery production has totally been transformed, primarily regarding its ownership structure. The general problem of this sector is that they can only spend slight amounts on development an innovation relative to foreign-owned concerns. As a consequence, loss of market is not surprising as a bit more than one-quarter (26-27 percent) of the current total domestic market turnover derives from domestic manufacturers. The extent of market loss and the general situation of the Hungarian agricultural machinery manufacturers justify that the present of this sector must be dealt with by searching the ways-out of the crisis and make steps to develop. Before the change of the regime only 27 agricultural machinery plants operated mostly "embedded" in the system of the Hungarian "agri-business". Due to this fact (among others), 60 percent of the requirements for agricultural machinery in the country were covered by these plants at a more advanced standard than the average of the former Comecon countries. During the past 15-20 years the organisational structure of the Hungarian agricultural machinery production has totally been transformed. Generally, the machine manufacturers operating as small-or medium-sized enterprises appear on the market with "separate" products usually not developed by themselves. Consequently, they are not price-setters, rather price takers. The product line of the companies that are successful in the international competition primarily consists of mass-produced and highly automated products. The Hungarian agricultural machinery manufacturers-partly due to their size- are not able to mass-produce in such an extent that they could compete with the West-European, American and Asian companies of huge capital power either in productivity, price or product range. A drastic innovation wave could mean a break out of this situation. Regarding innovation, the Hungarian agricultural machinery manufacturers also significantly lag behind as they can only spend slight amounts on development relative to foreign-owned concerns. As a consequence, loss of market is not surprising as a bit more than one-quarter (26-27 percent) of the current total domestic market turnover comes from domestic manufacturers.

METHODS

The basic objective of the research is to explore and analyse the innovation activity of the Hungarian agricultural machinery manufacturers, its results and influencing factors. Finally our objective is to have a picture of the innovation activity of the organisations involved, the special features of innovations, the partners taking part in the processes and the impact of innovation on the general situation of the companies through our examinations. Besides the brand-new or significantly developed products and technological procedure innovations, organisational features, marketing activity and the environment of the innovation are also considered. The questionnaire serving as the basis of primary research embraces three years, from 2007 to 2009. According to the estimations of experts the number of agricultural machinery manufacturing companies is between 160 and 170 in Hungary. (A great part of the enterprises are involved in more than one activity: a lot of predominantly small enterprises are also engaged in other activities besides machinery production so that is why it is difficult to define the actual number of 'agricultural machinery manufacturers' exactly). Most of the organisations that are subject to our analysis are small enterprises whose annual revenue does not reach one billion HUF. As there was not an available list on all the companies on the basis of which a pattern of probability could have been compiled, the companies that could be drawn into the research had to be defined in another way. To find the companies necessary for carrying out the questionnaire, the address list of MEGOSZ (National Association of Agricultural Machinery Manufacturers) served as a basis and the heads of this professional organisation were also consulted.

Sample-taking cannot be regarded representative. However, during the research it was not our objective to draw conclusions that can be generalised for the basic population. Our basic objective was to give a thorough examination of innovation activity and to achieve it, we tried to select the organisations regarded to be suitable on the basis of preliminary professional considerations. As such a thorough examination dealing with the innovation activity of agricultural machinery manufacturers was not carried out in the past 25 years on a national level; we consider our research is to resolve discrepancies in the professional field.

In compliance with the general methodological requirements first of all some pilot questions were asked on the basis of which the questionnaire was finalised. Data recording took place between March 2010 and September 2010. The duration of in-depth interviews was various, typically 90-100 minutes per interview. A positive feature of them was that data providers mainly come from the senior management (chief executive officer, head of production or technical manager). In this way first-hand information on the general situation, actual projects and strategic plans of the organisation involved was gained besides the reliability of data. The atmosphere of the interviews was typically of honesty and intimacy. Some of our interviewees have already expressed their enquiry in our results. The questionnaires compiled on the basis of the interviews and sent out by post were also accompanied by a guide to filling in. A kind of evaluation of our preliminary work is that all the responding organisations gave answers that could be assessed. The statistical processing of data recorded by the questionnaires was carried out by using SPSS 13.0 programme.

RESULTS

The presentation of the sample included in the examination

The breakdown of the concerned enterprises by size is presented by Figure 1. The breakdown reflects that the SMEs, typical of the sector, are overrepresented. Of the responding enterprises, micro enterprises represent significantly less weight in comparison with the data of the sector. The reason for it is that it was not the objective of our research to analyse them in more details.

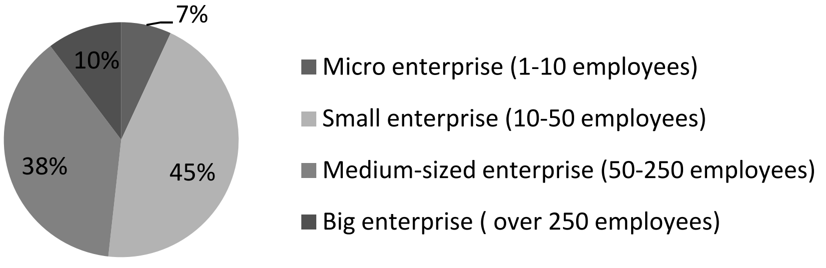

Figure 1 The breakdown of the enterprises concerned by size (Source: own research results)

We examined how much of their revenues the enterprises spend on innovation, research-development and marketing (Figure 2). In our experience the examined enterprises have realised the necessity of innovation in the marked areas. In this respect revenues show an increasing tendency despite the fact that the global economic crisis had several drawbacks in the growth of most companies. The companies spend hardly more than one percent of their revenue on marketing. This can also be explained by the fact that this sector is a typically neglected one as marketing-and advertising costs are the part of expenditures that enterprises can save most of in time of crisis.

In our questionnaires we separately dealt with the analysis of the role of foreign-owned innovation. Twenty-one percent of the companies involved indicated that they had foreign owners or part of its shares in foreign hands. The responses reflected that at companies owned by foreigners in 100 percent the desire for innovation is rather pushed in the background and the tasks of the national subsidiaries are limited to the launch of the products developed by the parent company in their plans and to ensure the maximum cost efficiency in production.

We also examined which markets the enterprises realise their revenue. It was an outstanding fact that the enterprises concerned sold their products on the Hungarian market in 72 percent and during the past three years there has not been a considerable shift in this area.

The exact numbers were completed by the in-depth interviews with the fact that one of the main intentions of the enterprises is to break successfully in foreign markets. However, most of them reported failures they faced. The reason for it derives from a lot of factors altogether: although their improved products have excellent value for money, they cannot compete with the local competitors mainly due to lack of a proper channel of distribution. Another problem is the resistance of the West-European farmers to less-known brands. The resources of the enterprises are depleted by demanding developments so they can hardly spend on marketing and PR activities, which would be essential in this sector.

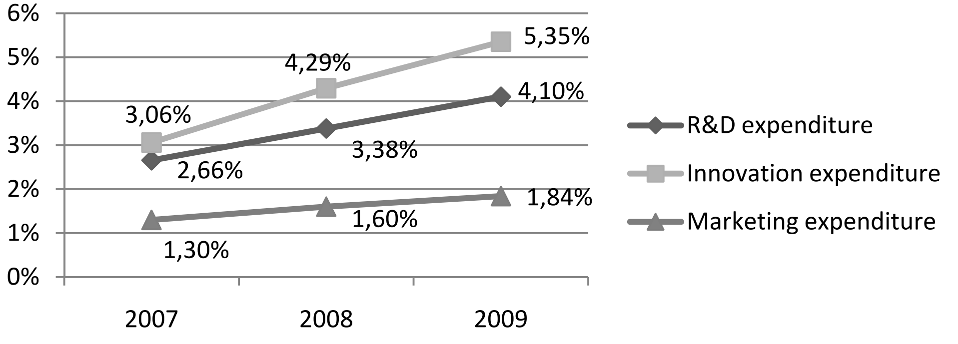

Figure 2 Expenditure on innovation, R&D and marketing (Source: own research results)

On the examined timeline 34 percent of the enterprises had a separate R&D department. The picture is made even more complicated by the fact that at the departments of such small-and medium-sized enterprises there are only one or two full-time employees to deal with the questions of innovation on the average compared to the big companies that can afford to operate R&D department with much bigger staff.

In the case of the marketing departments, the result was the same as 30 percent of the examined organisations had such a section. In this department typically one person in full time, or rather, part-time is employed to deal with marketing issues.

Forty eight percent of the examined enterprises operate in a linear form while 38 percent of them in a simple organisational one, i.e. they do not have functionally separated departments. This is a typical feature of the Hungarian small and medium-sized enterprises and it seems that agricultural machinery production is not the exception, either. SMEs have to realise that corporate functions and the development of the connections between them are more and more emphasised in creating competitive advantage as the change of technology and the process of product innovation do not only mean the qualitative transformation of technological parts or their quantitative development but also the development of complex mechanisms that help the interrelation between the single organisational functions/parts.

In research-development cooperation almost 80 percent of the companies concerned have already taken part in a form, which can be regarded a fairly good proportion. The decisive factors of R&D mark the most prominent direction of knowledge flow. These results reflect the demand driven nature of the Hungarian agricultural machinery innovations. Of the different sources of technical knowledge, companies place the greatest emphasis on getting to know the *clients' demands* (64%).

University research institutes were marked as second (60%) as the most important external partner in development.

It turns out from the results that the role of the different advisory organisations is low in development processes. The further inclusion of the intellectual capacity of experts from outside is made even more difficult by several factors. In the case of small-and medium-sized enterprises a significant hindering factor is the insufficiency of development resources so the rather expensive advisory companies seem to be beyond their reach (it can also explain why they turn to the university sector instead). Big companies employ professional staff and have a significant development capacity so they can cope with the problems arising on their own.

Only 15 percent of the responding companies stated that a kind of professional alliance had a role in their developments. Also, there are only few examples that competitors in the sector join their forces to achieve developments.

The characterisation of the market environment

Technological and market uncertainties have a profound impact on the operation of the company and makes a decisive influence on innovation processes-that is why their analysis is of high importance. In the following part we publish the results of our questionnaire in connection with the market environment. An answer was intended to find what changes the management think were made in the sector regarding market and technological uncertainties in the past three years. Also, the main reasons for this were also searched.

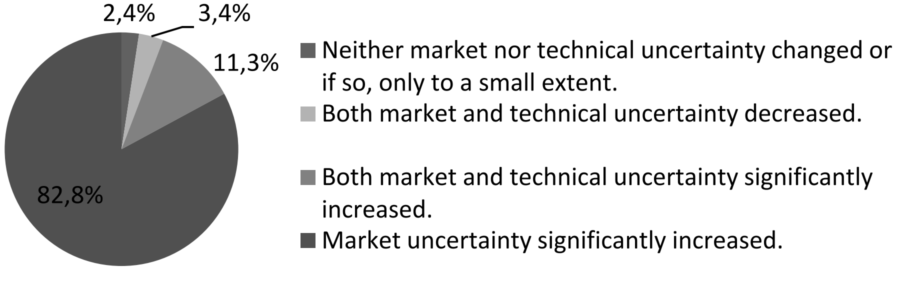

Figure 3 Changes in the sectoral environment (Source: own examination results)

Figure 3 shows that nearly 83 percent of the companies think that market uncertainties can strongly increase during the examined period. It is not surprising as due to the global financial crisis all the sectors of the Hungarian economy have had to tackle serious issues and pessimism has also become general. Almost all the respondents expressed their pessimistic opinions even during the small talk after the interviews had taken place.

Technical uncertainties have had a significantly slighter impact. One of the reasons for this can be that the sector does not change in a quick and predictable way when taking the basic technical considerations into account. Also, our results reflect that the main direction of innovations is developing the existing products so enterprises do not really dare to enter areas of uncertainties from technological point of view (except one). Some respondents made a complaint about spare parts of bad quality purchased from Chinese sources as a technical uncertainty.

If we examine the reasons for environmental uncertainties (Figure 4) the fact that organisations are aware of market and technical risks to a different extent is justified. The strongest environmental uncertainty is *increasing competition* (4.19) while the rapidly *outdating nature of technologies* (1.75) has the slightest impact. As mentioned earlier, the national producers are not price setters, rather price followers. So the *stronger competition from the cheaper producers* (3.68*) as well as the rising energy* (3.4) *and base material prices* (3.31) result in limited opportunities for the national agricultural machinery producers. Its direct impact on innovation activity is that producers cannot make funds /savings for development and very frequently they even lack the capital necessary for the project application. T he complexity of the products and the needs of the customers for development can be characterised by medium values regarding the other factors of uncertainty. However, it can be seen that the expectations of the clients for development have been growing in the past few years.

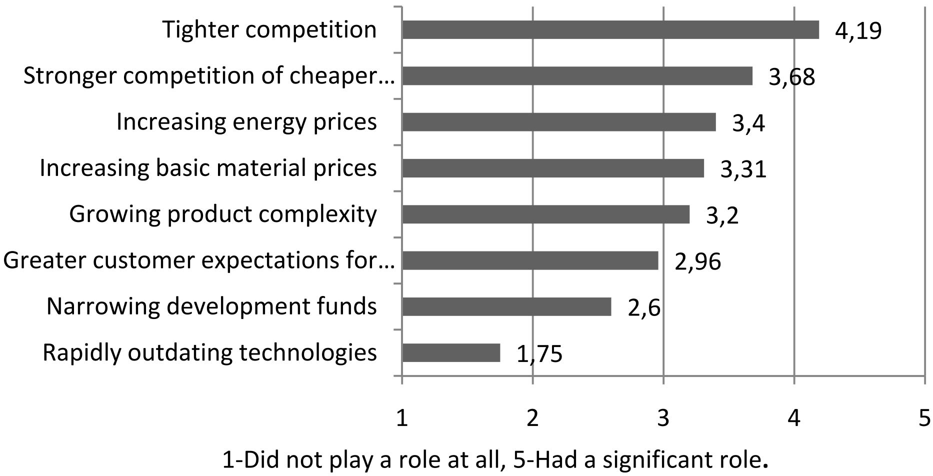

Figure 4 The reasons for uncertainties in the sectoral environment
(Source: own examination results)

An interesting result is that of the reasons for uncertainty *narrowing development sources* (2.6) play a minor role. According to the producers financing innovations typically takes place mainly from own capital by channelling back the profit without the inclusion of an external source (credit). That is why it is felt to a smaller extent that the risk taking role of the banks has significantly been decreasing and consequently made the financing of less predictable innovations more expensive. The rate of changing technologies can differ in the market of certain products. In line with the results above, the *rapidly outdating technologies* (1.75) in the case of agricultural machinery are not the factor of technical uncertainty.

Directions of agro-technical innovations

Based on our research 76 percent of he companies launched a new or a significantly modified product on the market during the examined period (2007-2009) and 69 percent carried out technological innovation.

The most determining direction of the R&D activity of agricultural machinery manufacturing companies is product development, which reflects the willingness to adapt to the continuously changing market needs. The common feature of the enterprises investing in innovation is their market proximity and user/customer-orientation. The sales opportunities of the manufacturers are determined by the fact to what extent they contribute to increasing the competitiveness of the farmers (enterprises) that make use of their new products. The improvement of existing products and constructions has a greater emphasis (71%) than the development of new products (66%). They are typically modifying-developing innovations that include the diversification of existing product lines with new products and the improvement of products, as well. The innovative features of the products are of wide range starting from the simplest solutions to the innovative products of great technical characteristic. As far as technological innovation is regarded, the main objective of most of the Hungarian manufacturers is the reduction of the production costs of their existing products and catching up in terms of efficiency indicators (60%). Of the forms of R&D activity the development of new technologies is of slighter importance. The refinement of existing producing processes can also play an important role in the competition as it is less expensive and not so risky than the development of a radically new technology. At the same time, its positive effect could rapidly be traced back in increasing efficiency, decreasing energy consumption, refinement of processing s well as the better quality features of the products.

The adaptation of procedures developed somewhere else was marked by 26 percent of the companies as part of R&D activity. The fact echoed so many times proved to be true again in this respect, i.e. one of the bottlenecks of agro-innovation is adaptation. As a possible form of innovation it is rather underestimated in the sector.

Factors that hinder innovation

When examining the results it is not surprising that most of all it is the high cost of innovation (3.42) that prevents Hungarian agricultural machinery manufacturing companies from their innovation activities like in the case of other companies in West Europe and other sectors of industry. Controlling innovation costs is rather problematic due to the uncertainties of the different sub-processes and their parts as unexpected costs can incur very frequently. Lack of state and project funds (3.08) is another significant hindering factor. However, our EU accession opened ways to innovation development sources but due to financing difficulties (slight share of own capital, credit regarded to be risky) only few agricultural machinery producers gain access to EU development funds. The separation of financial funds within the company (3.08) is a problem tightly linked to the previous one. A frequently made excuse is that the available funds are needed for other purposes so due to the necessity of ensuring everyday living uncertain developments are often sacrificed. High risk (2.81), taxation and its legal regulation (2.77) and the weakness of protecting intellectual property rights (2.28) are also seen as further obstacles. (When looking at the gained results it can be discerned that the respondents ranked the impact of even the strongest hindering factor to be approximately 3.5. This can be due to the special nature of the scale and the questionnaire as a statement with a negative content had to be evaluated.)

We also examined the human factors within the hindering factors of spreading innovation separately. The results are obvious as the factors in connection with lack of professionals and training are among the five most significant hindering ones. Unanimously the responding chief executives lack „good vocational staff" most typically for welding, CNC operator, mechanic and cutting positions. As far as graduates are concerned, there is a more intense need for traditional agricultural mechanics with language knowledge and production technician. The absence of technical professionals can go back to several reasons: the pulling power of other sectors regarding labour force is a problem and, furthermore, the small and medium sized agricultural machinery manufacturers cannot compete with the wages offered by the multinationals. As a further unfavourable process it was also mentioned that for the young it still was not too appealing to find placement at an agricultural machinery manufacturer in the countryside so labour supply often cannot be provided. Our findings also reflect that according to the chief executives the motivation of their subordinates does not hinder innovation processes. Interviews highlight that there was no resistance experienced among the employees (including the vocational staff of workshops), what is more, they are interested in a novelty, new developments and at several places new ideas are rewarded.

The managerial approach against novelties (1.2) was ranked the lowest of the different hindering factors. It is important to note as the literature on innovation management regards the support of the senior management as one of the key criteria of successful innovation, which, in more details, means making the necessary resources available, risk taking, creation of an atmosphere that supports creativity and an adequate system of incentives, monitoring the development process and participating in decision making at the key points most of all.

The success factors of innovation

In our questionnaire the criteria of the success of innovation were also analysed. An answer was sought to the question what factors the companies regard as the most essential ones for their successful innovation activities. Unanimously participation in professional exhibitions (4.32) was selected as the most significant success factor of implementing innovation. There can be two reasons why exhibitions are appreciated. On the one hand, the companies and their management can obtain first hand information on the developments of their competitors and the current market trends and it is also regarded as the primary means of marketing activities by the manufacturers as there is an opportunity of getting acquainted with new types, developments, different product and machinery (test) demonstrations in a concentrated form close to the potential customers, on the other hand. The ability of a quick technological reaction (3.93) was also regarded essential by the manufacturers in the innovation competition.

The further professional training of employees was ranked relatively high (3.75) among the key factors of innovation. According to our experience a great part of the national agricultural machinery manufacturers does not have strategic plans and ideas on human resources management in its classical sense. The gained results stress that the managers realised that they were somehow forced as the development of products and technologies also requires the necessity of training the engineers who develop and run them together with the vocational staff. That is why the above mentioned visits to professional exhibitions and fairs are a must together with exchanging professional points of view and organising further trainings for the employees. In some areas of vital importance such as product development, modern CAD technology and its application, optimising material content and TQM, regular updating and broadening knowledge is essential. At least organising the further trainings for SME managers and leaders is of similar importance. Courses, meetings and forums that shape attitudes, approaches and prepare the managers for managing innovation processes can help the creation of an atmosphere at work and a corporate culture that favour innovation. In the case of a small or medium sized enterprise the corporate culture must be adequate to *retain the valuable employees and run efficiently as besides salary, corporate atmosphere,* employee relations and those with the head of other companies are also decisive for the employee.

The creation of common innovation projects with universities and other research institutes (3.04) came last in the system of success factors but, of course, satisfactory did not mean degradation. The weak flow of knowledge between university and corporate spheres is not only the problem of this sector, e.g. European paradox, which is not a comfort in this concrete situation. The problem is quite complex and several research was conducted in it.

The partnership between the competitors and development co operations is under ranked in the sector (2.54). There are no forms of cooperation or partnerships; usually there are no agreements on cooperation, consortia and networks between the companies. In our opinion there are still significant reserves in this area. The partnership of companies provides further opportunities for the small and medium sized enterprises as participants to reduce their expenditure on certain areas such as technological investment, common procurement, developing foreign market relations (leaflets, advertisements, participation in exhibitions) joint marketing activity etc. besides sharing knowledge and technology transfer.

Innovation and strategy

Strategy in the competitive market is such a guideline of corporate function that defines the long-term goals and the system of means and methods that are necessary to reach them. Strategic planning plays an important role at all types of companies especially in the case of the innovative ones as it is they who dare to enter an uncertain area in its technical and economic sense due to their special activities. A thoroughly planned conscious strategy is the basis for creating innovations and operating an innovative organisation. Innovation strategy has to derive from and serve corporate strategy. The main point of innovation strategy is how the company can reach the market starting from research and development via product/service/technology production in the easiest way. An effective innovation strategy is implemented in a simple, concentrated way to a small extent so at the beginning scarce resources (funds, labour) are used and, simultaneously, the way out is also considered

At the time of the research almost 44.8 percent of the responding companies had a written corporate strategy and only 33 percent could present innovation strategy.

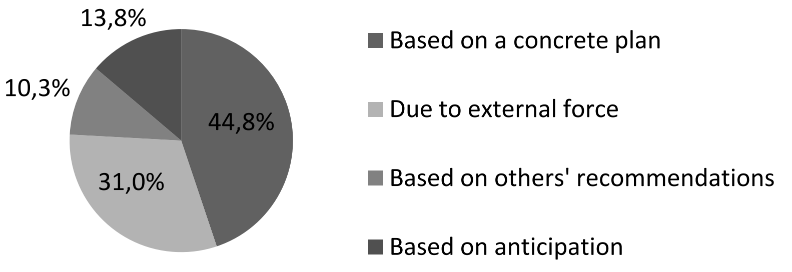

Figure 5 The main motives of innovation investment
(Source: own compilation)

Figure 5 illustrates the reason why the respondents decide on investing in innovation. Typically external forces (*31 percent*) explain why some of them lack a concrete conception on corporate running. Ten percent of them make a decision relying on other's opinion. The interviews revealed that mostly it is the business partner's recommendation and opinion that is reflected in the figures and nearly 14 percent make decisions based on anticipation.

Basically, innovation strategies can be of setting or following nature. The setting companies strive to have a leading role based on their technological advantages. At the same time, the application of this strategy incurs higher market and technological risks. It turns out from the examinations conducted so far that only a few national agricultural machinery producers are able to carry out setting innovation strategy. The relevant part of the questionnaire also justifies the statement and 22percent strive to carry out setting innovation strategy. The follower strategy is more widely uses (88%). The results so far also reflect that the national agricultural machinery manufacturers' aim at the user oriented further development of once introduced innovation and technological solutions. As they carry on with their former innovation results, the technical (technological) risk cannot be regarded really significant.

CONCLUSIONS

The characteristics of the Hungarian agricultural machinery manufacturers drawn in the examination illustrate the situation of the sector in the country. A decisive part of the organisations (83%) are small-and medium-sized enterprises. All in all, only about 26-27% of the national need for machinery derives from national manufacturers. Their attitude in development is reflected by the fact that more than 70 percent of their products are sold on the domestic market. As a result of their intention to increase export, one-quarter of their products are launched on foreign markets. Regarding the factors that influence their sales results we concluded that almost one-third of the examined organisations had a separate R&D department and the proportion of organisations that have a separate marketing department is similar.

Among the examined indicators of innovation performance the following ones must be highlighted:

- Organisations were spending more and more on R&D in the examined years, in 2009 it comprised 4.1 % of their average revenue. This value means a nominal increase of 154% relative to the one in 2007.
- Regarding the main directions of R&D activities it can be stated that most attention is paid to the development of the existing products (71%) and technologies (59%). Fewer companies are willing to deal with novelties, 66% are striving to develop new products and 52% to develop new technologies.
- Moe than 80% of the companies concerned have already been taking part in R&D cooperation. In these forms of cooperation, the proportion of the relationship with the customers is the highest, which indicates the priority of demand-driven innovations. It is also important to note that 60% is the proportion of partnerships with university research institutes.

The following must, by all means, be highlighted of the success and hindering factors of innovation explored during our analysis:

- The high costs of innovation, lack of financial funs within the company and the unfavourable system of state and project funds are such determining factors that can significantly limit the innovation scope of the Hungarian agricultural machinery manufacturers.
- Our examination justified the problem according to which the most acute problem of the sector is lack of vocational employees. Downsizing that can be experienced in the past 20 years makes it extremely difficult for the competitive agro-technical supporting industry to be established in the long run. It is obvious that the development and operation of the complicated agricultural mechanisms and technical subsystems is not viable without skilled staff. New expectations are formulated for the employees in accordance with the altered situation of small and medium sized enterprises.
- According to most respondents markedly one of the main bases of the successful innovation activity is visiting professional exhibitions. Manufacturers realised that machine exhibitions and fairs nowadays played the role of a complex marketing tool. They are a channel of communication through which the buyer and the seller can meet in time and space.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.1:658.5
Pregledni rad
Review paper

MANAGERIAL FEATURES OF MODERN AGRICULTURAL COOPERATIVES

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SUMMARY

In the context of Romanian legislation an agricultural cooperative association represents an autonomous individuals and/or legal, as appropriate, a private legal person, based on the freely expressed consent of the parties, in order to promote the interests of members, in accordance with cooperative principles, which is organized and operates according to this law. Agricultural cooperative is an autonomous association with an unlimited number of members, with variable capital, exercising an economic activity, and social engineering in the private interest of its members. Agricultural Cooperative does business, as producing goods and services in agriculture, aiming at providing the conditions for obtaining economic benefits to all their members, insurance requirements in supply cooperative members with the means of agricultural production, agricultural goods to obtain plant, animal and fish, according to market standards, creating conditions for agricultural products processing plant, animal and fish, getting the finished food quality standards and consumer market, capitalizing productions, social and economic development of the countryside. Agricultural cooperatives are based on the cooperative principles: open and voluntary association, equality in decision-making members of the administrative management of the cooperative activity, the economic participation of members, the autonomy and independence of the agricultural cooperatives of educating, training and informing members of the cooperative , of cooperation between agricultural cooperatives, the concern for sustainable development of communities. This paper presents some innovative principles of management features to be observed in conditions of modern capitalist society.

***Key words**: features, management, agricultural cooperative, autonomous association, capitalist society*

INTRODUCTION

The management features for the structural components of European agriculture are in changing in according with the technological and market situation. The agricultural cooperatives are increasingly lucrative in many countries, which are different as their miserable existence from the socialist camp.

The sustainable development of agriculture has been given an important place on the international and European agenda in the past few years, as recent trends in food prices and the food crisis show. The *Common Agricultural Policy* (CAP) has up to now been one of the fundamental elements of European cooperation and economic development and that will need to remain so in the future. But for that to be the case, radical changes in European agricultural policy will be necessary so as to link up with the reform measures that have been instituted in recent years. [7]

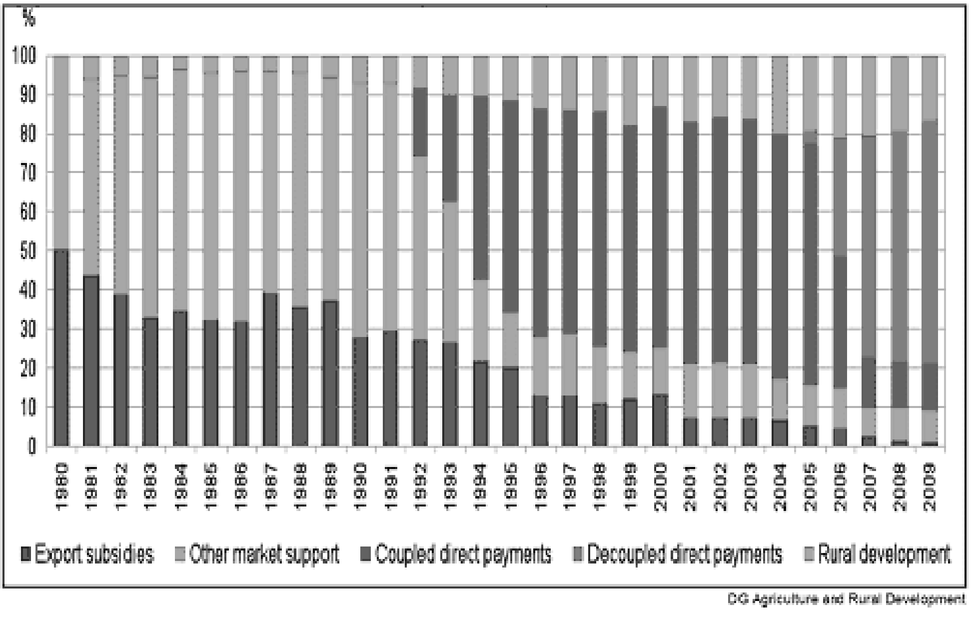

Figure 1 The CAP (Common Agricultural Policy) Budget (in % the total amount, after DG Agriculture and Rural Development. [6]

In *Figure 1,* show the evolution of some significant indicators, such as: Export subsidiary, other market support, coupled direct payments, decoupled direct payments, and rural development, in the last 20 years. It can see the substantial reduction of export subsidies, coupled direct payments and other market support, the growth of decoupled payments and, after a after an increase of rural development, in the first 10 years, followed of a period of stagnation, even a decrease of this indicator.

As a result, Romania's deficit in the farm and food trade has dropped by nearly 100 million euros, down to 606 million euros. Romania primarily exported raw materials, namely corn, tobacco or sunflower seeds. It is fair to say Romanian exports, cereal exports in particular have been favoured by soaring prices at global level throughout 2011. As regards Romanian imports, at the top of the list are sugar, sunflower seeds, fresh pork, corn, wheat and food preparations. [8]

Agriculture is considered one of the areas that could change the face of Romania, if it was put to best account. One impediment, however, is the very small average surface of farms, which does not allow for modern agriculture to be practiced. In other words, many farms are still engaged in subsistence agriculture.

As for the 2010-2011 farming year, it is expected to be better, mainly due to better weather, and the fact that, after many years, the government finally supplied the proper funds to farmers. Production this year stands at about 7 million tons, 80% of which can be used for bread making, while last year it was a mere 5.6 million tones. Corn is also expected to fare better as well.

European funds are granted through the 2007-2013 National Rural Development Program, whereby 7 billion Euros for agriculture and rural development programs are made available to individual and company agents.

The program also provides 2.72 billion Euros for direct payments to farmers. Total European funds for rural development grants will reach 10 billion Euros until 2013. Of this amount, Romania has so far accessed about 30%. [8]

Business management strategy can be illustrated as a process of specifying a company's objectives, developing policies and plans to achieve these objectives and the allocation of resources in the direction of implementing the policies and attaining these objectives. Most importantly, business management strategy is a dynamic process which encompasses all the industries and businesses in which the company is involved in a framework akin to that of game theory. These are good principles for agricultural cooperative management.

THEORETICAL APPROACH

For a better functioning of the mechanisms in the Romanian Agriculture, after 15 years after Revolution have been reintroduced agricultural cooperatives.

Currently in Romania, about the establishment and operation of agricultural cooperatives is Law no. 566/2004 - Law on Cooperatives Agriculture, updated in 2007.

Agricultural cooperative is an autonomous association of individuals and/or legal, as appropriate, the legal entity of private law, founded on the freely expressed consent of the parties, in order to promote the interests of members, in accordance with the cooperative principles, which are organized and function according to Law.

Agricultural Cooperative carries commercial activities, as producing goods and services in agriculture, following in this regard:

- Ensuring the conditions for obtaining economic benefits to all their members;

- Providing cooperative members in the supply requirements necessary means of agricultural production;
- Obtaining agricultural goods plant, animal and fish, according to market standards;
- Creation of conditions for agricultural products processing plant, animal and fish, getting finished food quality standards and consumer market;
- Using the production achieved;
- Economic and social development of the countryside.

Thus, it is considered that is a great need for the replication of the organizational forms in Romanian agriculture, on a new, modern and reliable, in terms of private property.

It is proposed to consider the model of Integrated System for Agro-Food Production (ISA-FP). An ISA-FP presumes a primary base, which became the start point for developing circles. The main piece of system is elimination of financial, law, economical barrier that can be found in usually, commercial, industrial, business. The stages in conception and planning integrated for a production system are: analyses of available personal resources; choose business; establish the main objectives for integrated system; create the strategy; financial and budget plan; elements for evaluation and monitoring the system. For ISA-FP one important characteristic is integration capacity, in the local, regional, national and the European economic system. The integration capacity represents the inter-connections level of ISAP in according with all the inter-dependence factors for a good function. In fact the integrated systems are as agro-industrial units, being constituted on the bases of a started action of usual a private initiative with a view to obtain a favorable material result. [1], [4], [5],

METHODS

For a better understanding of the phenomenon and to be closer to the realities of the state of the rural and Romanian agriculture, it was established the cooperative "NEW CENEI agricultural cooperative", being one among of the founders the author of this paper.

"NEW CENEI agricultural cooperative" has its headquarters in Cenei, Timis county. Cooperative develops business activities, it is producer for goods and services, following in this regard: - Ensuring conditions for obtaining economic benefits to all their members; - Ensuring the cooperative members requirements in the supply of the all are necessary for agricultural production; - Obtaining goods plant, animal and fish, in according with the market standards, - Creating of the conditions for agricultural products processing of plant, animal and fish, getting finished food at the market quality standards and at the consumer requirements; - Capitalization of production achieved; - Socio-economic development of the countryside.

"NEW CENEI agricultural cooperative" is a cooperative mining and agricultural land management, forestry, fisheries and livestock. The main activity, according to CAEN code is: the growing perennial (011), permanent (012) and multiplication (013) Livestock (014), activities in mixed farms (crops combined with farming of animals), (015) Support activities to agriculture and post-harvest activities, (016);

To design the cooperative structure it is considered necessary to adopt the principles of Integrated System for Agro-Food Production.

In this case, the management strategies can be established after the model presented in *Figure 2*, where ISA-PF in turn integrates into an agricultural cooperative, being in direct contact with professional associations and specialized domain. [5]

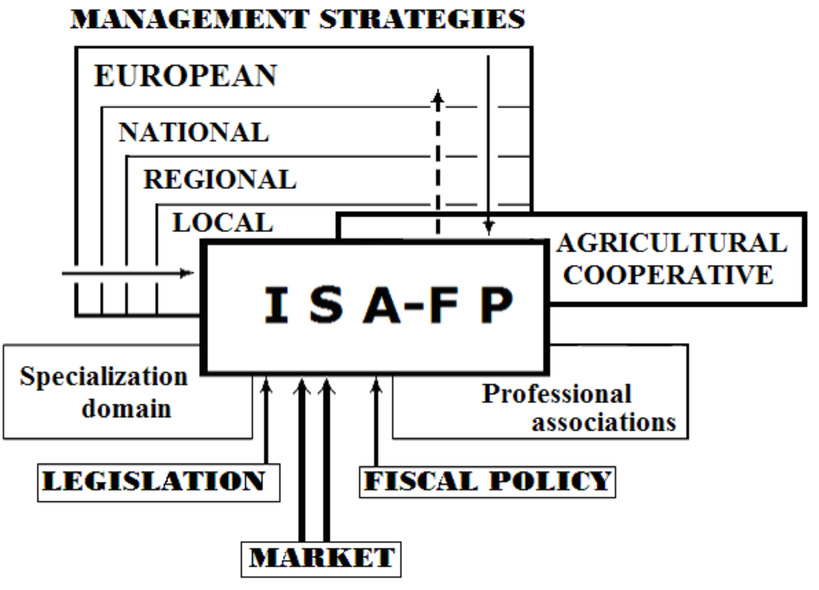

Figure 2 The principle of action optimized management strategies, considering the importance of agricultural cooperatives

For example, to understand the usefulness of an agricultural cooperative, consider grain elevators. These are often used for storing or drying grain, but most small farmers do not have the resources or time to purchase and build one of these structures on their own. Some projects aim to make farms simpler and more organic, and some want to use technology and advanced scientific thought to move agriculture forward. No matter the aim, the three basic types of agricultural projects are educational, promotional and research. Most projects encompass one, if not more, of these elements to help change the way farming is done. [2]

The principle of action proposed for optimized management strategies on the ISA-FP adds a greater influence from base to top, from the realities of the agro-food business by centralized structures of material.

In this way it can ensure the conditions of use all natural resources for ever-increasing food quality consistent with consumer needs.

The ISAFP can develop more harmonious; it can adapt more easily to slow down of the economy without the rational exploitation of natural environment. [1]

Management strategies for ISA-FP can be viewed from various approaches such as the industrial organization approach and the sociological approach based on human interactions and strong human relations between the lowest and highest level of managerial authority. There is also a strategy hierarchy that can be divided into functional strategy and operational strategy where functional strategies include marketing strategies, product development strategies, human resource strategies, financial strategies and information technology strategies as opposed to operational strategies which include the day-to-day functioning of the business or the corporate organization. In this context, we can mention the concept of the of Business Process Management (BPM) which is defined as the juncture between Business Management and Information Technology and deals with tools and techniques to design, control and analyze the operational business processes of a business. The main asset or quality of the business process management is the improvement in the business processes through new software tools called the BPM systems which have made such activities faster and cheaper. [7]

RESULTS AND DISCUSSION

The effect, in institutional, economic, social framework, supposed by Romanian integration in European Union implies a whole global process, in each components schedule, for quality administration.

The role of cooperatives as a critical dimension of market structure in agriculture must periodically be assessed to determine the future viability of the cooperative form of business.

New forces are impacting the farm economy at the dawn of the 21st century that requires the attention of cooperative business leaders. Recognizing the resiliency of self-help efforts directed to meeting member needs, focus group members addressed the new forces impacting farmers, rural communities and changing characteristics of markets. These forces, and suggestions about how to adjust to them, constitute a major part of the dialogue that focus group members engaged in during their deliberations. The compilation of thoughts and ideas contained in this report provides an important snapshot and reflection on cooperative principles, practices and structure by those on the firing line who are engaged in day-to-day operations. [9]

An agricultural cooperative, or farmers', does what all other cooperatives do, but it does so in a way that is specific to farmers. This may include pooling resources to buy seed, sell grain, store grain, or even help with marketing efforts. Often, an agricultural cooperative is involved in all of these matters.

These changes quite logically prove also under the development conditions of the current agriculture and the agricultural sector as a whole in its horizontal as well as vertical context. They overcome the formerly typical relative closeness of basic-industry segments. They affect the whole segment of economics connected with production, processing, distribution and realization of agricultural products and services related thereto. It can to change the size, rules as well as criteria of forming the offer and demand on agrarian markets, namely in whole verticals that these days frequently take the form of global networks. In their context, they may even interfere in the production and out-of-production relations of agriculture and complicate fulfilment of the segment.s multi-functional role within development of whole world regions. In this context, issues reappear concerning not just the amount of income redistribution for the benefit of agriculture in all dimensions of its mission, but these are also issues concerning effectiveness of the regulation forms and expedience of economic support for development of individual segments and increasing their competitiveness. [6], [7], [9]

CONCLUSIONS

The areas covered included the changing external and internal competitive environment, cooperative principles, structure of cooperative systems, governance and finance. Also addressed were issues associated with educational efforts and institutional mechanisms, such as public policy and government-sponsored support programs. Cooperatives are user-driven businesses that have contributed greatly to the development of one of the world's most productive and scientific-based agricultural systems.They have played an important role in strengthening market access and competitive returns for independent farm operators during the 20th century. They adapted their operations to agricultural technological innovations, such as the use of fertilizers, plant and livestock breeding, agricultural mechanization, electricity and other new sources of energy, and to new information systems.Cooperatives have also played an important role in rural communities, where they are an integral part of the social fabric. They encourage democratic decision making processes, leadership development and education.It's preferable to use the integrated systems for agri-food production, where can use minimum an available element (raw material source, the personal land, equipment for processing, personal network marketing, other).

After this brief analysis performed on agro-food market it can be concluded that agricultural European markets are unstable:

- Sensitivity of supply to climatic hazards (despite the technical progress)
- Supply is rigid in a short term (production cycle)
- Demand is inelastic (little variation depending on price).

In this case, for perspective, after the European Parliament the strategies for the EU are:

- Innovation and competitiveness of agribusiness
- Exchange rates in the long term (Euro / USD)
- Some hopes: growth of international trade;
- Export refunds were helpful especially in times of crisis (milk, sugar, pork,…)
- This justifies to maintain intervention prices at low level. [6]

Even in the absence of a strong policy steer to incentivise the production of bioenergy crops, European energy policy, market forces and the anticipated end of arable set-aside are likely to drive an expansion in the area and intensity of cereal production for bioenergy feedstocks over the next decade. Early trends bear witness to this 'cerealisation' of the European countryside, with concomitant adverse environmental affects.

A new set of policy drivers is emerging in rural Europe. Energy and climate goals are infiltrating a domain that has previously been dominated by food production and latterly sustainability concerns. These are likely to have implications for the future direction of the CAP, which has the capacity to influence land use decisions on a European scale, and raises questions about the relevance of current CAP objectives, the policy machinery required and the budget available for the sector in the longer term. [9]

For the modernization of agricultural cooperatives it is considered necessary to implement the ISA-FP principles in rural areas, with the sustainable links, both on horizontal and vertical of the structural levels of a united and integral European agriculture.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

VANJSKOTRGOVINSKA RAZMJENA REPUBLIKE HRVATSKE POLJOPRIVREDNO PREHRAMBENIM PROIZVODIMA

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SAŽETAK

Hrvatska je 1991. godine osamostaljenjem prešla sa planske na tržnu privredu, do sredine 90-ih godina trećina teritorija je bila okupirana i devastirana te će 2013. godine postati 28. članica Europske Unije. Sve je to, posebice ratna stradanja, utjecalo i na stanje nacionalne ekonomije. Jedno od glavnih obilježja navedenog razdoblja je deficit vanjskotrgovinske razmjene ukupno te i kod poljoprivredno-prehrambenih proizvoda. U 2010. godini ukupni vanjskotrgovinski deficit Hrvatske je bio 8,2 milijarde $. Poljoprivredni sektor sudjeluje sa 9,7% u vanjskotrgovinskoj razmjeni Hrvatske (prosjek 2005/10. godina), manje u uvozu (9,1%) nego u izvozu (10,9%). Vanjskotrgovinski deficit kod poljoprivredno prehrambenih proizvoda je između 695 milijuna $ u 2005. i 1.225 milijuna $ u 2008. godini. Od 2005. do 2010. pokrivenost uvoza izvozom kod poljoprivredno prehrambenih proizvoda je nešto povoljnija (58,7%) u odnosu na ukupnu vanjskotrgovinsku razmjenu (48,9%). Najznačajniji izvozni proizvodi Hrvatske su šećer od šećerne repe i trske, cigare i cigarete od duhana te čokolada, a uvozni prehrambeni proizvodi-ostali, svinjsko meso svježe te goveda. Najviše poljoprivredno prehrambenih proizvoda (oko trećine ukupnog) izvozimo u Bosnu i Hercegovinu, a najviše uvozimo iz Njemačke (11,8%) i Italije (11,6%).

Ključne riječi: *uvoz, izvoz, poljoprivredno-prehrambeni proizvodi, Republika Hrvatska*

UVOD

Međunarodna razmjena je posljedica unutrašnjih zbivanja u privredi, proizvodnji i potrošnji, odnosa ponude i potražnje, viškova i manjkova roba u gospodarstvu otvorenom prema svjetskom tržištu (Kovačević i Sabolović 2002.). Postoji snažna veza između vanjske trgovine i rasta društvenog proizvoda. Veće stope rasta ostvaruju države s uspješnim i konkurentnim izvoznim sektorima, razvijenim domaćim tržištem ili pristupom drugim tržištima (Balassa 1978). Općenito, u ekonomskoj teoriji rasta, prihvaćena je pozitivna korelacija između izvoza i ekonomskog rasta. Procijenjeno je da liberaliziran trgovinski sustav sa rastom izvoza za 1% pridonosi 0,7 % višoj stopi rasta BDP-a, u odnosu na ostale sustave gospodarske sustave (Balassa 1978).

Recesija je izazvala strukturne promjene svjetskoga gospodarstva pri čemu je uočljiv proces tržišnoga repozicioniranja i to ponajprije u realnome sektoru ekonomije. Model razvitka hrvatskoga gospodarstva mora se zasnivati na izvoznoj orijentaciji gospodarstva, a osobito na izvoznoj orijentaciji prerađivačke industrije. (Buturac i sur. 2009).

Vanjskotrgovinska razmjena poljoprivredno-prehrambenih proizvoda ovisna je o domaćoj proizvodnji, razvijenosti industrije prehrambenih proizvoda, stvarnoj i potencijalnoj domaćoj potražnji, promjenama na svjetskom tržištu i sl. te je cilj Hrvatske da koristeći svoje poredbene prednosti ostvari što veći izvoz uz što manji uvoz.

MATERIJAL I METODE

U radu se istražuje vanjskotrgovinska razmjena Hrvatske za razdoblje od 2005. do 2010. godine, ukupna te posebno razmjena poljoprivredno-prehrambenih proizvoda i to prema proizvodima i izvozno-uvoznim odredištima. U radu se polazi od pretpostavke da je pokrivenost uvoza izvozom kod poljoprivredno prehrambenih proizvoda viša nego kod ukupne vanjskotrgovinske razmjene Hrvatske i da se vanjskotrgovinska razmjena odvija sa relativno malim brojem država.

Za potrebe istraživanja korišteni su podaci Državnog zavoda za statistiku (DZS) i Hrvatske gospodarske komore (HGK), a kao kvantitativni pokazatelj vanjsko-trgovinske razmjene korišten je indikator „pokrivenost uvoza izvozom“. Ukoliko je vrijednost indikatora pokrivenosti ispod 1 ostvaruje se vanjsko-trgovinski deficit i obratno, ako je indikator veći od 1 prisutan je vanjsko-trgovinski suficit. Kao relativni pokazatelj indikator se često iskazuje i u postotku.

REZULTATI I DISKUSIJA

Izvozne mogućnosti i uvozna ovisnost nacionalne ekonomije odraz su dostignute razine konkurentnosti njezinih gospodarskih subjekata i njihove proizvodnosti.

Vanjskotrgovinska razmjena Hrvatske povećala se tijekom analiziranog razdoblja pri čemu je veći porast ostvaren kod izvoza nego kod uvoza. Uvoz i izvoz bilježe porast do 2008. godine kada su i najveći, a nakon toga čega dolazi do smanjenja pri čemu je smanjenje veće kod uvoza. Karakteristika cijelog razdoblja je veliki vanjskotrgovinski deficit koji je također najveći u 2008. godini (16,6 milijardi $), a nakon toga se smanjuje.

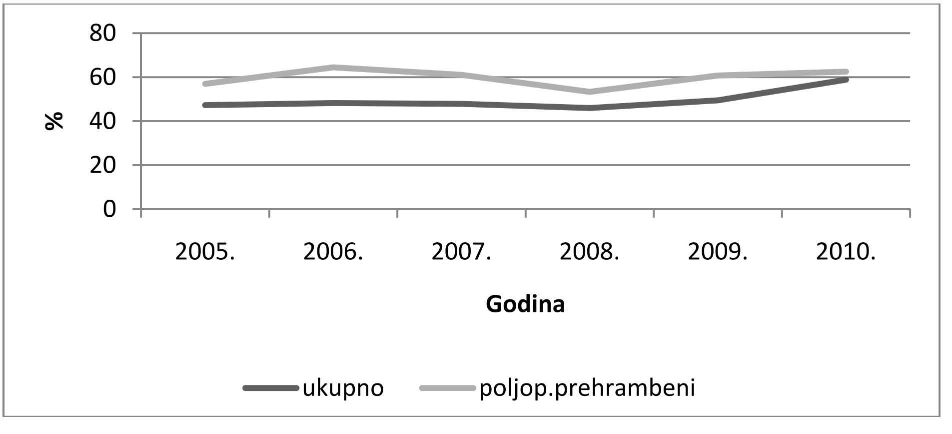
Slične promjene bilježe se i kod vanjskotrgovinske razmjene poljoprivredno-prehrambenih proizvoda. Do 2008. godine brži je porast uvoza nego izvoza, a nakon toga dolazi do njihovog smanjenja pri čemu je, slično kao i kod ukupne vanjskotrgovinske razmjene, veće smanjenje uvoza. Promjene do 2008. godine jednim dijelom mogu se pojasniti velikim rastom svjetskih cijena poljoprivredno-prehrambenih proizvoda ali i dijelom porasta količinskog uvoza. Saldo vanjskotrgovinske razmjene poljoprivredno-prehrambenih proizvoda je negativan tijekom cijelog razdoblja i najveći je bio 2008. godine.

Tablica 1 Vanjsko-trgovinska razmjena Republike Hrvatske (milijuna $)

	Ukupno			**Poljoprivredno-prehrambeni proizvodi**				
Godina	**Izvoz**[1]	**Uvoz**[1]	**Saldo**	**Izvoz**	**Uvoz**	**Saldo**	**Udio (%) u izvozu**	**uvozu**
	1	**2**	**3**	**4**	**5**	**6**	**7 (4/1)**	**8(5/2)**
2005.	8.024	18.560	-10.536	920	1.615	-695	11,5	8,7
2006.	10.376	21.502	-11.126	1.190	1.847	-657	11,5	8,6
2007.	12.363	25.838	-13.475	1.313	2.150	-837	10,6	8,3
2008.	14.123	30.726	-16.603	1.399	2.625	-1.226	9,9	8,5
2009.	10.491[2]	21.204[2]	-10.713	1.360	2.239	-879	13,0	10,6
2010.	11.806[2]	20.053[2]	-8.247	1.355	2.168	-813	11,5	10,8

Izvor: [1]Državni zavod za statistiku- Statistički ljetopis 2009; [2]Hrvatska gospodarska komora-Odabrani gospodarski pokazatelji 1995.-2010

Značajan pokazatelj je i udjel poljoprivredno prehrambenih proizvoda u ukupnom izvozu odnosno uvozu. Tijekom cijelog razdoblja veći je udjel poljoprivredno-prehrambenih proizvoda u izvozu, sa značajnijim kolebanjima, nego u uvozu gdje pokazuju lagani ali stalni porast. Poljoprivredno prehrambeni proizvodi, prosjek razdoblja, u uvozu su imali udjel od oko 9% te izvozu oko 11%.



Slika 1 Pokrivenost uvoza sa izvozom od 2005. do 2010. godine, preračunato prema "Uvoz i izvoz po proizvodima carinske tarife i zemljama porijekla" (tab 45. i tab 46.), za razdoblje od 2000. – 2010., DZS RH

Značajan indikator vanjsko-trgovinske razmjene je pokrivenost uvoza sa izvozom. Na njega djeluje mnoštvo čimbenika kako sa uvozne tako i sa izvozne strane, a zajedničko im je količina, kvaliteta i cijena.

Hrvatska vanjskotrgovinska bilanca je negativna odnosno pokrivenost uvoza izvozom je značajno ispod 100.

Iako Hrvatska ne može biti zadovoljna rezultatima vanjskotrgovinske razmjene u sektoru proizvodnje hrane, činjenica je da su rezultati bolji u odnosu na druge proizvodne grane. Tijekom cijelog analiziranog razdoblja pokrivenost uvoza izvozom je kod poljoprivredno prehrambenih proizvoda veća od ukupne vanjskotrgovinske razmjene (prosjek razdoblja je kod poljoprivredno-prehrambenih proizvoda 59,6%, a za ukupnu 48,7%). Na navedene promjene u početku razdoblja značajan utjecaj je ulazak Hrvatske u WTO), a nakon 2008. godine kada se smanjuje vanjskotrgovinska razloge možemo pronaći u globalnoj ekonomskoj krizi.

Iako je tijekom analiziranog razdoblja značajna vrijednosna promjena vanjskotrgovinske razmjene poljoprivredno prehrambenih proizvoda (porast uvoza sa 1.615 na 2.168 te izvoza sa 920 na 1.355 mil. $) struktura izvoza i uvoza se nije značajnije mijenjala.

U tablici 3 prikazan je udjel deset najznačajnijih proizvoda i skupina proizvoda, prema carinskoj tarifi, u ukupnom izvozu. Navedeni proizvodi, kao prosjek razdoblja, čine preko polovice ukupnog izvoza.

Već duže razdoblje hrvatski najznačajniji izvozni proizvod je šećer kako zbog ostvarenog napretka u proizvodnji šećerne repe i preradi u šećer, tako i zbog uspješnog repozicioniranja u pretpristupnom razdoblju Hrvatske u Europsku uniju u koju se izvozi glavnina šećera.

Unatoč antiduhanskoj kampanji Hrvatska je uspjela sačuvati „duhanski“ sektor koji je drugi po izvoznom udjelu proizvod. Na trećem mjestu je čokolada i drugi proizvodi iz CT 1806. Značajno mjesto u izvozu ima riba i to morska. Značajne udjele imaju pivo i mineralna vode što je posljedica novijih akvizicija hrvatskih kompanija u zemljama okruženja.

U uvoznoj strukturi poljoprivredno prehrambenih proizvoda značajnija je disperzija proizvoda. Tako deset po udjelu najznačajnijih čine „samo“ 35,7% ukupnog uvoza poljoprivredno prehrambenih proizvoda.

Posebno zabrinjava visoko pozicioniranje uvoza svinjskog mesa i goveda, a uvoz CT 1701 predstavlja uvoz šećera od šećerne trske.

Oko 80% hrvatskog izvoza je u deset zemalja od čega je izvan Europe jedino Japan (najviše zbog izvoza tunjevine). Ovakva distribucija izvoza ima dobre i loše osobine. Dobra strana je da hrvatski izvoznici dobro poznaju ukuse potrošača izvoznih odredišta te i potrošači prepoznaju hrvatske proizvode. Loša strana je što se ne koriste mogućnosti izvoza na puno veća tržišta kao što je Rusija, zemlje bliskog istoka itd.

Blizu polovice hrvatskog izvoza plasira se u zemlje bivše Jugoslavije pri čemu je na prvom mjestu Bosna i Hercegovina. Međutim, istodobno skoro 40% izvoza ostvaren je u zemlje Europske unije.

Tablica 2 Deset najzastupljenijih proizvoda u izvozu poljoprivredno prehrambenih proizvoda Hrvatske (Ukupan izvoz = 100)

CT	Naziv	2005	2006	2007	2008	2009	2010	Prosjek
1701	Šećer od šećerne repe i trske	14,7	15,2	15,2	10,6	8,9	9,1	12,1
2402	Cigare i cigarete od duhana	12,7	8,4	7,9	7,7	6,4	6,5	8,0
1806	Čokolada i drugi proizvodi	7,8	12,0	4,4	4,1	4,2	4,1	5,9
0302	Riba svježa ili rashlađena	5,0	8,0	6,1	3,9	6,5	5,3	5,8
2103	Preparati za umake	5,5	4,3	4,0	4,7	4,1	4,1	4,4
2106	Prehrambeni proizvodi-ostali	3,9	4,3	3,7	4,9	4,7	4,3	4,3
1905	Kruh, peciva,kolači i ostalo	3,1	2,4	2,8	3,5	3,3	3,6	3,2
1001	Pšenica i napolica	0,0	1,1	7,6	0,1	4,0	4,6	3,1
2203	Pivo proizvedeno od slada	2,6	2,7	2,4	3,4	2,9	2,6	2,8
2202	Voda mineralna gazirana	1,7	1,7	2,5	3,8	3,1	3,5	2,8

Izvor: Isti kao za Sliku 1

Tablica 3 Deset najzastupljenijih proizvoda u uvozu poljoprivredno prehrambenih proizvoda Hrvatske (Ukupan izvoz=100)

CT	Naziv	2005	2006	2007	2008	2009	2010	Prosjek
2106	Prehrambeni proizvodi-ostali	5,1	4,8	5,2	5,1	4,9	5,0	5,0
0203	Svinjsko meso svježe	5,7	4,7	4,2	3,5	5,4	4,8	4,7
0102	Goveda	5,0	4,7	4,0	3,7	3,9	4,0	4,1
1701	Šećer od šećerne repe i trske	4,4	9,1	4,6	3,6	2,2	1,1	4,0
1905	Kruh, peciva,kolači	3,6	3,6	3,8	3,7	4,2	4,5	3,9
2309	Proizv. za životinjsku ishranu	3,1	3,0	3,2	3,3	3,8	3,9	3,4
1806	Čokolada i drugi proizvodi	2,8	2,7	3,0	2,7	3,5	3,7	3,1
2304	Uljane pogače	2,0	2,1	2,5	3,2	3,6	2,6	2,7
0901	Kava, pržena ili nepržena	2,5	2,5	2,8	2,4	2,5	2,6	2,5
0406	Sir i urda	2,6	2,2	2,4	2,0	2,1	2,4	2,3

Izvor: Isti kao za Sliku 1

Za promatrano razdoblje, najveći partneri koji su kupovali hrvatske poljoprivredno prehrambene proizvode su Bosna i Hercegovina, Italija, Slovenija, Austrija i Njemačka i vrijednost izvoza u te države je nešto iznad polovice ukupnog izvoza. Na kraju analiziranog razdoblja zamjetno je smanjenje izvoza u Italiju i Austriju što je djelomično nadoknađeno povećanjem udjela izvoza u Sloveniju.

Tablica 4 Prvih deset izvoznih odredišta poljoprivredno prehrambenih proizvoda Hrvatske (Ukupan izvoz=100)

	2005.	2006.	2007.	2008-	2009.	2010.	Prosjek
BiH	30,5	24,9	32,2	36,4	32,3	30,6	31,3
Italija	18,8	16,2	15,8	8,5	12,5	10,7	13,4
Slovenija	7,4	7,3	8,5	9,2	8,9	9,8	8,6
Srbija	6,3	6,6	6,4	8,2	1,0	6,8	5,8
Njemačka	4,1	6,4	4,4	4,4	4,1	4,8	4,7
Austrija	5,1	5,8	4,1	4,6	3,6	2,7	4,2
Japan	3,9	7,4	4,8	1,6	4,3	3,1	4,1
Mađarska	2,9	3,9	3,2	4,1	2,7	3,4	3,4
Slovačka	1,2	2,4	0,8	1,4	9,8	1,2	2,9
Makedonija	2,7	2,0	2,4	2,8	2,6	2,8	2,5

Izvor: Isti kao za Sliku 1

Za očekivati je da će se ulazak Hrvatske u EU negativno odraziti na međusobnu vanjskotrgovinsku razmjenu jer će Hrvatska izgubiti preferencijalni tretman na tržištu Bosne i Hercegovine. Slično se desilo i Sloveniji. Dakle, da bi Hrvatska održala svoj udjel na tržištu BiH ona svakako mora povećati konkurentnost vlastitog izvoza u tu zemlju. (Matić i sur. 2010)

Kod uvoza je zamjetno nešto drugačije stanje nego kod izvoza. Prvih deset zemalja iz kojih Hrvatska uvozi sudjeluju sa oko 66% ukupnog Hrvatskog uvoza. I ovdje su dominantne europske zemlje i jedino je, ali na trećem mjestu prisutan Brazil (zbog uvoza govedine). Tako nešto iznad polovice ukupnog uvoza je iz zemalja Europske unije, dočim iz zemalja okruženja (bivše Jugoslavije) samo oko 8%.

U razdoblju od 2005. do 2010. godine najvažnije države iz kojih smo najviše uvozili njihovih poljoprivredno-prehrambenih proizvoda bile su Njemačka sa tendencijom rasta uvoza, Italija gdje zadržavamo stalno približno jednaki udio u ukupnom uvozu, Brazil. Austrija i Slovenija kod kojih država je prisutan lagani pad udjela uvoza, a kod uvoza iz Bosne i Hercegovine prisutan je trend povećanja uvoza.

Činjenica da je Europska unija najznačajniji vanjskotrgovinski partner Hrvatske ulazak u integraciju proširiti će se izvozno tržište Hrvatske i liberalizacijom dati dodatni poticaj međusobnoj trgovini (Kersan 1998).

Posebno za Hrvatsku su interesantna susjedna tržišta sa kojima Hrvatska ostvaruje različitu razinu vanjskotrgovinske razmjene i ima različitu vanjskotrgovinsku bilancu.

Tablica 5 Prvih deset uvoznih odredišta poljoprivredno prehrambenih proizvoda Hrvatske (Ukupan uvoz=100)

	2005.	2006.	2007.	2008-	2009.	2010.	Prosjek
Njemačka	10,4	11,2	10,7	11,1	13,2	13,8	11,8
Italija	11,8	12,2	11,5	11,7	11,2	11,3	11,6
Brazil	6,5	6,3	9,1	8,7	7,6	6,4	7,6
Nizozemska	6,1	6,3	6,5	6,6	7,8	8,4	7,0
Mađarska	6,6	5,7	6,7	8,6	6,1	5,6	6,6
Austrija	7,3	6,3	5,9	5,3	5,0	4,6	5,6
Poljska	4,8	4,6	4,1	3,9	4,2	4,4	4,3
Slovenija	5,3	4,8	4,7	4,3	3,4	3,3	4,2
BiH	3,3	3,2	3,9	4,2	4,8	5,3	4,2
Španjolska	4,0	4,3	4,5	3,5	3,6	3,0	3,7

Izvor: Isti kao za Sliku 1

Tablica 6 Vanjskotrgovinska bilanca Hrvatske kod poljoprivredno prehrambenih proizvoda sa odabranim državama (izvoz/uvoz)*100

Država	2005	2006	2007	2008	2009	2010	Prosjek
BiH	528	501	502	415	412	362	439
Crna Gora			2630	2593	3638	3511	3021
Makedonija	92	77	86	78	81	87	83
Slovenija	77	97	112	102	176	190	123
Srbija	152	237	155	209	148	135	163
Ukupno	215	229	246	232	245	236	236

Izvor: Isti kao za Sliku 1

Hrvatska sa navedenim državama ukupno ima pozitivnu ukupnu vanjskotrgovinsku bilancu i to od 221 mil. $ u 2005. do 451 mil. $ u 2009. godini.

Najveću vanjskotrgovinsku razmjenu tijekom analiziranog razdoblja Hrvatska je imala sa Bosnom i Hercegovinom (52,8%), zatim sa Slovenijom (22%), Srbijom (15,7%), znatno manje sa Makedonijom (7,5%) te Crnom Gorom (3,1%). Hrvatska tijekom cijelog razdoblja jedino sa Makedonijom te u prve dvije godine sa Slovenijom ima deficit, a sa ostalim državama ostvaruje suficit kod vanjskotrgovinske razmjene poljoprivredno prehrambenih proizvoda.

ZAKLJUČAK

Saldo vanjskotrgovinske ukupne i razmjene poljoprivredno-prehrambenih proizvoda Hrvatske je negativan tijekom cijelog analiziranog razdoblja, ali povoljniji u odnosu na ukupnu vanjskotrgovinsku razmjenu. Pokrivenost uvoza izvozom je kod poljoprivredno prehrambenih proizvoda veća nego kod ukupne vanjskotrgovinske razmjene (prosjek razdoblja je kod poljoprivredno-prehrambenih proizvoda 59,6%, a za ukupnu 48,7%). Najznačajniji hrvatski izvozni proizvodi su šećer i duhan, a uvozni svinjsko meso i goveda. Glavnina vanjskotrgovinske razmjene ej sa Europskom unijom pri čemu najviše izvoz i u BiH (preko 30% ukupnog izvoza), a uvozi iz Njemačke (11,8%) i Italije (11,6%). Sa zemljama okruženja (ex-Jugoslavije) Hrvatska ostvaruje, izuzev Makedonije, značajan suficit kod razmjene poljoprivredno prehrambenih proizvoda. Kako bi Hrvatska povećala svoj udjel u vanjskotrgovinskoj razmjeni poljoprivredno prehrambenih proizvoda potrebno je povećati konkurentnost proizvoda u kvaliteti i cijeni. Da bi se smanjila uvozna ovisnost neophodno je brže ići na promjenu strukture izvoza ka proizvodima koje traži svjetsko tržište. Uspješna primjena instrumenata izvozne potpore u agrarnoj politici uz stalno praćenje kretanja na svjetskom tržištu, te bržoj specijalizaciji i diferencijaciji poljoprivrednih proizvoda mogla bi značajno doprinijeti povećanju izvozne konkurentnosti hrvatske poljoprivrede. (Zmaić i sur. 2006)

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CROATIAN FOREIGN TRADE OF AGRICULTURE AND FOOD PRODUCTS

IVO GRGIĆ, VLADIMIR LEVAK, MAGDALENA ZRAKIĆ

SUMMARY

In 1991 Croatian became independent state and moved from planned to a market economy. By mid 90-ies the third of territory was occupied and destroyed. In 2013 will become the 28th member of the European Union. All that, especially the suffering of war, affected the condition of national economy. One of the main features of this period was the total trade deficit and also the deficit in agricultural and food exchange. In 2010 the total Croatian trade deficit was $ 8.2 billion. The agricultural sector participates with 9.7% of total Croatian foreign trade (average for 2005/10), less in import (9.1%) than in export (10.9%). The foreign trade deficit in agricultural food products was between $ 695 million in 2005 and $ 1225 million in 2008. From 2005 to 2010 the coverage of import by export of agricultural and food products is somewhat more favourable (58.7%) compared to the total foreign exchange (48.9%). The most important Croatian export products are sugar beet and cane sugar, cigars and tobacco cigarettes and chocolate and imported food products are other commodities, fresh pork and beef. The most of agricultural and food products (about a third of the total) are exported in Bosnia and Herzegovina and mostly imported from Germany (11.8%) and Italy (11.6%).

Key words: *import, export, agricultural and food products, The Republic of Croatia*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.17:711.3
Prethodno priopćenje
Preliminary communication

RURALNI PROSTOR I POLJOPRIVREDNA TEHNIKA

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SAŽETAK

U radu se daju rezultati ankete eksperata o stanju ruralnog prostora i poljoprivredne tehnike u Bosni i Hercegovini, Hrvatskoj, Srbiji, Rumunjskoj i Turskoj. Iako su pojedine države prošle različiti povijesni razvitak, osnovna obilježja ruralnog prostora i stanje poljoprivrednike tehnike su slična. Ruralni prostor je i dalje prvenstveno poljoprivredni prostor, demografski devastiran i infrastrukturno nerazvijen u odnosu na urbani dio države. Poljoprivreda kao dominantna privredna djelatnost ruralnog prostora na prijelazu je iz tradicionalne u suvremenu sa u prosjeku malim proizvodnim jedinicama nedovoljnim za ekonomski opravdano korištenje u pravilu starije poljoprivredne tehnike. Budući poljoprivredni i ruralni razvitak promišlja se slično ali i različito s razloga specifičnosti poljoprivredne proizvodnje svake od država sudionica ankete

Ključne riječi*: ruralni prostor, poljoprivreda, tehnika*

UVOD

Ruralni prostor se u suvremenom ekonomskom pristupu shvaća kao područje od osobite važnosti i zbog toga se njemu posvećuje posebna pozornost kroz kreiranje novih mjera i programa za njegov razvoj. Slijedeći europske trendove, mnoge države prepoznaju vrijednosti svog ruralnog prostora, uvažavajući njegove brojne lokalne specifičnosti, koje proizlaze, ne samo iz povijesti i tradicije, već i iz geografskog položaja, prometne povezanosti ili izoliranosti i/ili blizine urbanih središta. Općenito, razvitkom ekonomskih odnosa, poljoprivreda, kao osnovna djelatnost u ruralnom prostoru, gubi na svom značenju, iako u mnogim državama još uvijek ima dominantnu ulogu. Nasuprot tome, povećava se stambena i turistička funkcija ruralnog prostora, a razvitak prometne infrastrukture čini ga sve dostupnijim kao odredištem za odmor ili zabavu. Mnoštvo je problema prisutnih u ruralnom prostoru od koji su neki zajednički i za cijelu zajednicu. Jedan od najvećih problema je nezaposlenost te nedostatak mladog i stručnog stanovništva. U najvećoj mjeri je to posljedica nedostatka malih pogona/firmi primjerenih ruralnom prostoru kao i nedostatka stručne podrške za poduzetništvo. I poljoprivreda se susreće sa mnoštvom problema od pri čemu se kao najčešći ističe nesređeno tržište koje uključuje problem otkupa poljoprivrednih proizvoda, cijene, nedostatne količine neujednačene kakvoće, nelojalna konkurencija. Značajan problem za poljoprivrednike osim visokih cijena inputa predstavlja veličina posjeda i njegova opremljenost poljoprivrednom tehnikom. Poljoprivredna tehnika osim proizvodnog učinka u ruralni prostor unijela je mnoštvo promjena. Ona nije samo nadomjestak za manjak radne snage i čimbenik povećanja proizvodnosti te s time i dohotka proizvođača i stanovnika ruralnog prostora općenito. Ona je veliki pokretač nužnosti novih znanja (tehničkih, tehnoloških i ekonomskih) kod korisnika odnosno kod poljoprivrednih proizvođača. Poljoprivredna tehnika je ušla u do tada očuvano prirodno okruženje sa mogućnošću i neželjenih posljedica utjecaja na okoliš kao što su pogonska goriva i maziva, neadekvatno zbrinjavanje otpada i sl. Obilježja ruralnog prostora kao i vrsta, dob i uporaba poljoprivredne tehnike, posebno strojeva, su različita po pojedinim državama što ovisi o njihovom povijesnom razvoju, ekonomskoj snazi pojedinih država, zemljopisnim obilježjima, izvanrednim katastrofama (prirodne, ratovi i sl.) te su i različiti postupci u daljnjem unapređenju „sljubljenosti prostora i tehnike“. U većini zemalja svijeta ruralne oblasti suočene su s brojnim problemima: pad standarda, migracija u urbane oblasti, smanjenje materijalnih i ljudskih resursa, negativne posljedice po životnu sredinu i drugo. To predstavlja ekonomski, socijalni, demografski i kulturološki problem. Stoga se ruralni razvoj razmatra u mnogim zemljama svijeta, a fokusira ga i Europska unija. Svjetska organizacija za poljoprivrednu tehniku CIGR, uočavajući ovaj problem, osnovala je radnu grupu *Rural Development and Preservation of Cultural Heritages*. Cilj ove radne grupe je sagledavanje mogućnosti struke, *Agricultural and Biosystems Engineering*, da doprinese razvoju ruralnih oblasti. Grupa djeluje na svjetskoj razini, a probno istraživanje provedeno je u regiji Jugoistočne Evrope. Ovo istraživanje ima za zadatak provjeriti postavljenu metodu, anketiranje relevantnih i stručnih osoba, s namjerom ispunjenja postavljenog cilja na svjetskoj razini.

MATERIJAL I METODE

Velika je uloga poljoprivredne tehnike u razvitku poljoprivrede i društveno-ekonomskih promjena u ruralnom prostoru. Zbog toga se pojavila ideja za istraživanjem značenja poljoprivredne tehnike u ruralnom prostoru nekoliko država pri čemu ovo istraživanje predstavlja jedan oblik testiranja važnosti problematike. Istraživanje je provedeno u mjesecu kolovozu i rujnu 2011. godine namjernim odabirom ispitanika primjenom za to posebno kreirane „Ankete eksperata“. Anketirano je ukupno 80 ispitanika različito po državama i to u Bosni i Hercegovini (6), Hrvatskoj (41), Srbiji (13), Rumunjskoj (14) i Turskoj (6) U istraživanje se pokušalo uključiti Bugarsku i Kosovo, ali nažalost to nije uspjelo. Anketni upitnik se sastojao od tri dijela. U prvom dijelu ispitanici su rangirali važnost ponuđenih djelatnosti za ruralni prostor njihovih zemalja od potpuno nevažno do iznimno važno. Drugi dio sastoji se od 25 konstatacija kojima se pokušalo istražiti osnovne probleme korištenja poljoprivredne tehnike pri čemu su ispitanici na pojedine izjave mogli odgovoriti od potpuno se slažem (5) do uopće se ne slažem (1) tj. Likertova skala od 5 stupnjeva. U trećem dijelu (34 konstatacije) istražuje se doprinos poljoprivredne tehnike razvoju poljoprivredne proizvodnje i ruralnog prostora sa Likertovom skalom od 4 stupnja. Obrada je obavljena SPSS (Statistical Package for Social Sciences) programskim paketom, a podaci su prikazani tabelarno korištenjem aritmetičke sredine ($\bar{y}$) i standardna devijacija (σ_y)

REZULTATI I DISKUSIJA

Ruralni prostor je sve heterogeniji po ekonomskoj strukturi pri čemu se tijekom vremena mijenja značenje pojedine djelatnosti. Nastale promjene često ne znače i poželjne i očekivane promjene od strane domicilnog pučanstva. Ispitanici najvažnijom djelatnošću svoga ruralnog prostora su procijenili stočarstvo, a shodno poznatoj komplementarnosti sa ratarstvom ono se našlo na drugom mjestu. Značaj poljoprivrede za ruralni prostor potvrđen je i trećim i četvrtim mjestom važnosti voćarstva i vrtlarstva. Ruralni prostor je povijesno u sebi sadržavao specifične oblike obrtništva kojega ispitanici percipiraju kao jednog od oblika veće zaposlenosti i dohotka ali i kao djelatnost koja čuva ruralni krajolik. Trgovina razvitkom velikih trgovačkih centara „povlači se iz susjedstva“ te se sve više osjeća njen nedostatak u ruralnom prostoru (nadomjestak je često putujuća trgovina). Ugostitelji objekti najčešće su bili i društvena središta događanja, a u simbiozi razvitka ruralnog turizma bili bi dobar oblik šire uslužne ponude.

Često se prenaglašava uloga i mogućnosti ekološke poljoprivrede, te ju i ispitanici smatraju važnom za ruralni prostor, ali svjesni su poteškoća s proizvodne strane (proizvodna tehnologija) tako i u sferi trženja (skupi proizvod). Slično je i sa seoskim odnosno agroturizmom. Iako postoje mogućnosti njihovog razvitka posebice sa potražne strane (sve je više urbanog stanovništva) oni su prilika za manji dio ruralnog stanovništva jer agroturizam traži i više zahtjevne sposobnosti, ali i odmak od rutinirane svakodnevnice na koju su proizvođači navikli.

Rasadničarstvo te cvjećarstvo u prosjeku angažiraju više radne snage specifičnijih znanja, te su i zbog toga manje važni za ruralni prostor. Na začelju važnosti su industrija i građevinarstvo kako zbog tradicionalno njegovog manjeg značenja tako i zbog želje da se ruralni prostor ne devastira.

Postoje određene razlike između pojedinih država zbog povijesnih događanja ali i zbog veličine uzorka odnosno broja ispitanika. Tri po važnosti od anketiranih rangirane djelatnosti su vrtlarstvo, stočarstvo te cvjećarstvo i ukrasno bilje (Hrvatska), vrtlarstvo, voćarstvo i stočarstvo (Rumunjska) te voćarstvo, cvjećarstvo i ukrasno bilje te stočarstvo (Turska). Nešto drugačiji je slijed kod Srbije (ratarstvo, stočarstvo te trgovina i ugostiteljstvo) kao i kod Bosne i Hercegovine (industrija, cvjećarstvo i ukrasno bilje te vrtlarstvo).

Kod konstatacije kao manje važnih djelatnosti za ruralni prostor pojedinih država u Hrvatskoj su građevinarstvo, ratarstvo i rasadničarstvo, u Rumunjskoj trgovina i ugostiteljstvo, građevinarstvo i ratarstvo, u Srbiji su građevinarstvo, cvjećarstvo i ukrasno bilje te rasadničarstvo, u BiH ekološka poljoprivreda, ratarstvo i građevinarstvo te u Turskoj industrija, obrtništvo te trgovina i ugostiteljstvo. Poljoprivredna tehnika zahtjevna je sa stajališta znanja i troškovno je značajna posebno u poljoprivrednoj proizvodnji tradicionalnih obilježja koju karakterizira relativno mali posjed, nekvalificirana radna snaga, niska razina profitabilnosti itd. Ispitanicima smo ponudili 25 konstatacija za koje su mogli odgovoriti sa potpuno se slažem, slažem se, do uopće se ne slažem.

Tablica 1. Važnost poljoprivrednih grana i nekih nepoljoprivrednih djelatnosti za ruralno područje (potpuno nevažno=1, nevažno=2, važno=3, vrlo važno=4, iznimno važno=5)

Table 1 Importance of the agricultural branches and some non-agricultural activities for rural areas (completely unimportant= 1, unimportant= 2, important= 3, very important= 4, especially important= 5)

	$\bar{y}$	σ_y
Stočarstvo (Animal production)	4,12	0,868
Ratarstvo (Arable production)	3,91	0,983
Voćarstvo (Orchard production)	3,67	0,971
Vrtlarstvo (Vegetable production)	3,66	1,034
Obrtništvo (Handycrafts)	3,13	1,068
Trgovina i ugostiteljstvo (Trade and catering	3,03	1,124
Ekološka poljoprivreda (Organic production)	3,01	1,130
Seoski turizam, agroturizam (Farm tourism)	2,99	1,198
Rasadničarstvo (Seedling)	2,87	0,869
Cvjećarstvo i ukrasno bilje (Flower and herbs production)	2,79	0,991
Industrija (Industry)	2,74	0,979
Građevinarstvo (Building industry)	2,61	0,876

Izvor: Anketa CIGR WG Rural Development and Preservation of Cultural Heritage u 2011.
Source: Enquiry CIGR WG RDPCH in the year 2011

Ispitanici ispravno povezuju značenje poljoprivredne tehnike i ljudi tj. njihovog znanja o poljoprivrednoj tehnici gdje u simbiozi postižu najbolje efekte. Najvažnija tvrdnja da „bez obzira na svoju dob proizvođači moraju ovladati novim tehnikama“ poljoprivreda se iz tradicionalne djelatnosti pomiče prema suvremenoj kapital intenzivnoj, od djelatnosti preživljavanja prema djelatnosti specijalizacije i profesionalizma. I s druge strane, za veći i snažniji ulazak novih tehnika u poljoprivrednu proizvodnju preduvjet su školovani stručnjaci kako u području proizvodnje tako i u području usluga. Ali općenito, za bavljenje poljoprivrednom proizvodnjom nužno je veće znanje pa sve do toga da se predlaže čak i polaganje ispita koji bi u ovom slučaju uključivao i poznavanje poljoprivredne tehnike.

Poljoprivredna tehnika i nove tehnologije sukladno tome, po mišljenju ispitanika doprinijeli su porastu poljoprivredne proizvodnje daleko više od korištenja drugih inputa u poljoprivredi. Poljoprivredna tehnika je ne samo kompleksna nego i relativno skupa u odnosu na ostale poljoprivredne inpute. Efikasnije korištenje može se povećati ili povećanjem prosječnih obradivih površina ili zajedničkim korištenjem strojeva pri čemu se kao jedan od boljih oblika pokazao tzv. „strojni prsten“.

Tablica 2. Problemi korištenja poljoprivredne tehnike - pet konstatacija sa kojima se anketirani najviše i pet sa kojima se najmanje slažu (odgovori: potpuno se slaže=5; slaže se=4; nema mišljenje=3; ne slaže se=2; uopće se ne slaže=1)

Table 2 Issues of farm machinery utilization - the highest and the lowest 5 agree statements (completely agree= 5, agree= 4, haven't attitude=3, don't agree= 2, completely disagree= 1)

	$\bar{y}$	σ_y
Pet s najvećim suglasjem - The highest 5 agree statements		
Bez obzira na dob poljoprivrednici trebaju ovladati novim tehnikama Regardless of age level farmers need to acquire skills for managing new machinery and technologies	4,25	0,626
U uvođenju i ovladavanju poljoprivrednom tehnikom velika je uloga za to školovanih stručnjaka Introduction and implementation of new farm machinery demands properly educated experts	4,17	0,725
Poljoprivredna tehnika najviše je doprinijela povećanju poljoprivredne proizvodnje u svijetu Agricultural Engineering was the most significant and influential factor of world's agricultural production increase	4,13	0,848
U korištenju poljoprivredne tehnike nove generacije potrebno je udruživanje proizvođača u strojne prstene Rational use of new generation farm machinery demands joining farmers into machinery rings	4,09	0,944
Za bavljenje poljoprivrednom proizvodnjom potrebno je položiti ispit koji će obuhvatiti i poljoprivrednu tehniku Professional farmers should have essential knowledge of agricultural & biosystems engineering that will be proved by proper checking	3,89	0,914
pet sa najmanjim suglasjem the lowest 5 agree statements		
Oprema je glavni ograničavajući faktor povećanja poljoprivredne proizvodnje Equipment is primary factor that limits agricultural production	2,96	1,174
Trendovi zaštite okoliša ograničavaju uporabu poljoprivredne tehnike	2,93	1,065
Novitete poljoprivredne tehnike (informatika, displey itd.) treba prepustiti mlađima Novelties within agricultural & biosystems engineering (IT, robotics etc.) should leave younger generation to cope with	2,91	1,186
Iskoristivost strojeva na gospodarstvu je dovoljna Farm machinery and equipment at Your farm is adequatly used	2,87	13024
Današnja poljoprivredna tehnika jedan je od većih zagađivača okoliša Current agriculture machinery is one of the greater environment polluters	2,48	1,125

Source: Enquiry CIGR WG RDPCH in the year 2011

Iako se problem tehnike često prikazuje kao bitan čimbenik efikasnije poljoprivredne proizvodnje, poljoprivredna tehnika u našem istraživanju nije glavni ograničavajući faktor povećanja poljoprivredne proizvodnje. Također i očuvanje okoliša već duže vrijeme je značajno pitanje ruralnog prostora, ali to ne ograničava značajnije uporabu poljoprivredne tehnike posebno ako se ona ispravno koristi. Anketirani smatraju da poljoprivredna tehnika nije veći zagađivač prostora. Da bi se ona ispravno koristila odnosno neki noviteti kao što su GPS, informatika, displey itd. nije bitna dobna granica korisnika nego nužnost poznavanja noviteta. Znatno veći problem za anketirane je nedovoljna iskoristivost strojeva.

Kod problema korištenja poljoprivredne tehnike uočljive su razlike između pojedinih zemalja.

U Hrvatskoj je visoka suglasnost da novitete poljoprivredne tehnike treba prepustiti mlađima i da je za bavljenje poljoprivrednom proizvodnjom nužan ispit koji obuhvaća i poljoprivrednu tehniku, ali i da je znanje poljoprivrednika dostatno za upotrebu suvremene tehnike. Anketirani smatraju da je poljoprivredna tehnika najviše doprinijela povećanju poljoprivredne proizvodnje u svijetu, ali i da više doprinosi profitu onih koje je proizvode nego profitu poljoprivrednika. Prema njima, mala je uloga školovanih stručnjaka u uvođenju i ovladavanju poljoprivrednom tehnikom. Nedovoljne su površine za raspoloživu poljoprivrednu tehniku, koja je relativno suvremena ali s time nije i jamac profitabilne poljoprivredne proizvodnje. Poljoprivredna tehnika nije najzahtjevnija u pogledu ovladavanja novinama u odnosu na druge novine u poljoprivrednoj proizvodnji.

U Rumunjskoj anketirani smatraju da je u korištenju poljoprivredne tehnike nove generacije potrebno udruživanje u strojne prstene. Dob poljoprivrednika nije prepreka ovladavanju novim tehnikama, ali novitete ipak treba prepustiti mlađima. I u Rumunjskoj smatraju da poljoprivrednici moraju položiti ispit koji će obuhvaćati i poljoprivrednu tehniku koja je najviše doprinijela povećanju poljoprivredne proizvodnje u svijetu. Nedovoljne su površine za raspoloživu poljoprivrednu tehniku koja nije od većih zagađivača okoliša. Razvitak poljoprivredne tehnike ovisi o potrebama poljoprivrede, a strojevi i oprema nisu zastarjeli i ne zahtijevaju veće napore poljoprivrednika u ovladavanju korištenja.

I u Srbiji smatraju da je u korištenju poljoprivredne tehnike nove generacije potrebno udruživanje u strojne prstene. Dob poljoprivrednika nije prepreka ovladavanju novim tehnikama pri čemu je tu velika uloga za to školovanih stručnjaka. U bliskoj budućnosti uloga poljoprivrede će biti značajnija zbog proizvodnje biomase kao obnovljivog izvor energije, a danas je na tržištu mnoštvo polovne mehanizacije koja je i nedovoljno iskorištena. Zbog toga se ne može biti konkurentan na tržištu poljoprivrednih proizvoda. Noviteti poljoprivredne tehnike trebaju biti dostupni svima bez obzira na dob. Poljoprivredna tehnika jedan je od manjih zagađivača okoliša.

Anketirani u BiH smatraju da novitete poljoprivredne tehnike treba prepustiti mlađima, ali bez obzira na dob svi poljoprivrednici trebaju ovladati novim tehnikama. Također smatraju da je potreban ispit koji će obuhvaćati i poljoprivrednu tehniku koja je po njima najviše doprinijela povećanju poljoprivredne proizvodnje u svijetu. Poljoprivredne strojeve novije generacije bolje je unajmiti nego imati vlastite. Poljoprivredna tehnika nije glavni ograničavajući faktor povećanja poljoprivredne proizvodnje ali nije i najzahtjevnija za poljoprivrednike u pogledu ovladavanja novinama. U BiH postoje dovoljne površina da bi se iskoristila raspoloživa poljoprivredna tehnika koja na tržište dolazi sve više kao polovna i ne jamči profitabilnu poljoprivrednu proizvodnju.

Tablica 3. Čimbenici sa doprinosom poljoprivrednom i ruralnom razvitku - pet na vrhu i pet sa začelju utjecaja (odgovori: vrlo značajan utjecaj=4, značajan=3, bez mišljenja=2, nema utjecaja=1)

Table 3 Factors that influence agriculture and rural development- 5 highest and 5 lowest influence factors (answers: very important=4, important=3, no opinion=2, not important=1)

	$\bar{y}$	σ_y
pet sa najvećim doprinosom - the highest 5 agree statements		
Uvođenje novih, suvremenih, postupaka poljoprivredne proizvodnje Introduction of new, modern, agricultural production processes	3,73	0,446
Razvoj infrastrukture: putovi, vodoopskrba, električna mreža itd. Establishing of infrastructure: roads, water supply, electricity supply etc..	3,66	0,552
Pravilno korištenje strojeva i opreme Proper machinery and equipment using	3,58	0,546
Proširenje poljoprivredne proizvodnje na postžetvene postupke, napr. sušenje i prerada… Introducing of post-harvest processes, like drying, processing, etc..	3,41	0,610
Proizvodnja i korištenje obnovljivih izvora energije na bazi lokalnih potencijala i resursa Production and using of renewable energy sources according to local are possibilities and capacities	3,39	0,775
pet sa najmanjim doprinosom - the lowest 5 agree statements		
Razvoj obrazovnih institucija u ruralnom području Establishing education institutions to rural areas	2,84	0,926
Utemeljenje malih izložbi, muzeja mehanizacije i seoskog života Foundation of small exibitions and museums dedicated to machinery and rural type of life	2,83	0,796
Razvoj mini industrijskih/zanatskih parkova Foundation of mini industrial/handcrafts parks	2,82	0,997
Lokalna proizvodnja strojeva i opreme u malim i srednjim poduzećima Foundation of small and midium local area firms for machinery and equipment production	2,72	1,061
Premještanje dijelova javnih istraživačko-razvojnih institucija u ruralna područja Transfering of some parts of public research-development institutions to rural areas	2,67	1,022

Source: Enquiry CIGR WG RDPCH in the year 2011

U Turskoj anketirani smatraju da je poljoprivredna tehnika najviše doprinijela povećanju poljoprivredne proizvodnje u svijetu. Nedostatne su površine za raspoloživu poljoprivrednu tehniku te je potrebno udruživanje proizvođača u strojne prstene. Znanje je dostatno za upotrebu suvremene tehnike i bez obzira na dob poljoprivrednici trebaju ovladati novim tehnikama. Proizvodnja biomase kao obnovljivog izvor energije neće povećati u bliskoj budućnosti ulogu poljoprivrede, a današnja poljoprivredna tehnika nije veći zagađivač okoliša. Poljoprivredna tehnika je bitna svim proizvođačima i nije zahtjevnija za proizvođače u pogledu ovladavanja novinama. Neosporno je da poljoprivredna tehnika pridonosi povećanju poljoprivredne proizvodnje te s time i razvoju ruralnog prostora. Osim nje na ruralni i poljoprivredni razvitak utjecaj je i mnoštva drugih čimbenika iz i izvan ruralnog prostora. Prema ovom istraživanju, uvođenje novih, suvremenih, postupaka poljoprivredne proizvodnje ima najveći utjecaj na povećanje poljoprivredne proizvodnje te s time i na druge promjene unutar ruralne sredine. Na povećanje poljoprivredne proizvodnje veliki utjecaj je pravilnog korištenja strojeva i opreme. Nejednoliko korištenje uvjetovano sezonskim karakterom najvećeg dijela proizvodnje naglašava potrebu proširenja poljoprivredne proizvodnje na postžetvene postupke kao što su. sušenje i prerada. Više za ruralni nepoljoprivredni prostor je bitna proizvodnja i korištenje obnovljivih izvora energije na bazi lokalnih potencijala i resursa te razvitak vodoopskrbne i električne mreže itd.

Zabrinjava da bi, prema anketiranim, razvoj obrazovnih institucija u ruralnom području imao mali utjecaj. Sličan doprinos razvitku imalo bi i utemeljenje malih izložbi, muzeja mehanizacije i seoskog života. Ne očekuju mnogo više niti od razvoja malih industrijskih/zanatskih parkova, lokalne proizvodnje strojeva i opreme te od premještanja dijelova javnih istraživačko razvojnih institucija u ruralna područja.

U Hrvatskoj, prema mišljenju ispitanika, poljoprivrednom i ruralnom razvitku najviše će pripomoći provedba stalnog obrazovanja kao što su kratki kursevi, obuka, seminari između ostalog i o pravilnom korištenju strojeva i opreme te organizirana nabavka mehanizacije i drugih inputa za poljoprivrednu proizvodnju. Značajnim smatraju i organiziranu razmjenu iskustava sa stanovnicima drugih naselja i regija kao i mogućnost proizvodnje i korištenja obnovljivih izvora energije na bazi lokalnih potencijala i resursa. Na poljoprivredni i ruralni razvitak znatno niži je utjecaj razvitka nepoljoprivrednih djelatnosti kao što su radionice za održavanje, popravke i remont mehanizacije, proizvodnja tradicionalnih pića, zatim prerade i finalizacije poljoprivrednih proizvoda, introdukcija obrazovnih institucija te čak i razvoj određene infrastrukture (putovi, vodoopskrba, električna mreža itd.).

U Rumunjskoj na poljoprivredni i ruralni razvoj najveći utjecaj ima pravilno korištenje strojeva i opreme što bi podržavale lokalne radionice za održavanje, popravke i remont mehanizacije. Preduvjet tome je i provedba stalnog obrazovanja u ruralnim područjima: kratki kursevi, obuka, seminari. Također bitnim se smatra i proširenje poljoprivredne proizvodnje na postžetvene postupke te proizvodnja obnovljivih sirovina za industriju. Znatno mani utjecaj je organizirane razmjene iskustava sa stanovnicima drugih naselja i regija, uvođenje novih, suvremenih, postupaka poljoprivredne proizvodnje i introdukcija obrazovnih institucija. Razvitku bi neznatno pomoglo formiranje strukovnih udruženja poljoprivrednika i stanovnika ruralnih područja te proizvodnja i korištenje obnovljivih izvora energije na bazi lokalnih potencijala i resursa

Na stanje poljoprivrede i ruralnog prostora Srbije veliki utjecaj ima uvođenje novih, suvremenih, postupaka poljoprivredne proizvodnje te pravilno korištenje strojeva i opreme čemu je preduvjet razvoj adekvatne infrastrukture: putovi, vodoopskrba, električna mreža itd. Anketirani smatraju bitnim razvoj i primjenu mjera ostvarenja održive poljoprivredne proizvodnje kao i prikupljanje i zbrinjavanje unutar poljoprivrede otpadnog materijala. Nasuprot tome, na poljoprivredni i ruralni razvitak neznatan je utjecaj proizvodnje tradicionalnih jela i pića, organiziranje proslava karakterističnih za područje, npr. "Dani krastavaca", razvoj jeftinijih strojeva i opreme sa karakteristikama koje zadovoljavaju lokalne potrebe kao i formiranje malih izložbi, muzeja mehanizacije i seoskog života.

Anketirani u BiH smatraju da veliki utjecaj na poljoprivredni i ruralni razvoj ima pravilno korištenje strojeva i opreme čemu je pretpostavka proširenje poljoprivredne proizvodnje na postžetvene postupke. Znatnim smatraju i izgradnju malih industrijskih i zanatskih objekata u ruralnim područjima što uključuje i proizvodnju strojeva i opreme. Puno manji utjecaj bi imale organiziranje proslava karakterističnih za određeno područje, razvoj obrazovnih institucija kao i premještanje dijelova javnih istraživačko razvojnih institucija u ruralna područja. Neznatan utjecaj je i primjena mjera ostvarenja održive poljoprivredne proizvodnje te proizvodnja i korištenje obnovljivih izvora energije na bazi lokalnih potencijala i resursa. Slični rezultati su dobiveni i u Turskoj. I oni značajnim smatraju pravilno korištenje strojeva i opreme i razvoj jeftinijih strojeva i opreme sa karakteristikama koje zadovoljavaju lokalne potrebe, organiziranu razmjenu iskustava sa stanovnicima drugih naselja i regija. Značajnim smatraju i mogućnost proširenja poljoprivredne proizvodnje na postžetvene postupke te proizvodnju obnovljivih sirovina za industriju. Neznatan utjecaj je proizvodnje tradicionalnih jela i pića kao i razvoj seoskog turizma. Slično je i sa formiranjem mini industrijskih/zanatskih parkova te prikupljanjem i zbrinjavanjem otpadnog materijala.

ZAKLJUČAK

Ruralni prostor je sve heterogeniji po ekonomskoj strukturi pri čemu se tijekom vremena mijenja značenje pojedine djelatnosti, ali poljoprivreda je još uvijek dominantna. To potvrđuje i naše istraživanje gdje u značajnosti za ruralno područje poljoprivredne grane zauzimaju prva četiri mjesta (stočarstvo, ratarstvo, voćarstvo i vrtlarstvo). Ekološka poljoprivreda i ruralni turizam bitni su za manji dio stanovnika. Industrija i građevinarstvo su najmanje bitni za ruralni prostor. Poljoprivredna tehnika ima veliko značenje za poljoprivrednu, te time i ruralni razvitak. Najvažnija tvrdnja da „bez obzira na svoju dob proizvođači moraju ovladati novim tehnikama“ pokazuje da se poljoprivreda iz tradicionalne djelatnosti pomiče prema suvremenoj kapital intenzivnoj, te od djelatnosti preživljavanja prema djelatnosti specijalizacije i profesionalizma. I s druge strane, za veći i snažniji ulazak novih tehnika u poljoprivrednu proizvodnju preduvjet su školovani stručnjaci kako u području proizvodnje, tako i u području usluga. Ali općenito, za bavljenje poljoprivrednom proizvodnjom nužno je veće znanje pa sve do toga da se predlaže čak i polaganje ispita koji bi u ovom slučaju uključivao i poznavanje poljoprivredne tehnike. Prema ovom istraživanju, uvođenje novih, suvremenih, postupaka poljoprivredne proizvodnje ima najveći utjecaj na povećanje poljoprivredne proizvodnje te s time i na druge promjene unutar ruralne sredine. Na povećanje poljoprivredne proizvodnje veliki utjecaj je pravilnog korištenja strojeva i opreme.

ZAHVALA

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RURAL AREA AND AGRICULTURAL ENGINEERING

S. KOŠUTIĆ, I. GRGIĆ, M. MARTINOV, G. FABIJANIĆ

SUMMARY

Paper presents enquiry results of agricultural engineering experts attitude and opinion regarding rural areas economic, cultural current position and agricultural engineering influence to their future position and development. Enquiry covered Bosnia and Herzegovina, Croatia, Serbia, Romania and Turkey. Although some countries experienced different historical development, basic characteristics of rural areas and position of agricultural engineering are pretty similar. Rural areas are still primarly agricultural areas, although are demographically devastated and infrastructurally undeveloped in comparison to urban parts of countries. Agriculture is a dominant economic activity of rural areas and although in a transition state from traditional to a modern one, is characterised with very small average production area that is productionaly and economicaly unadequate to rationally exploit even older generation of farm machinery. Almost all enquired experts regardless of their home country origin invisage future alike but in the same time a bit different which influenced specifics of agricultural production of its country origin. This research and analysis revealed introduction of new modern production processes as the most influential factor on agricultural production increase, inducing thus some other positive changes into a rural areas. Another highly ranked influential factor was that increase of agricultural production is influenced by proper farm machinery and equipment using.

Key words: *Southeast European countries, rural area, agriculture engineering, prospect*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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WATER DROPLET TRAJECTORIES IN AN IRRIGATION SPRAY: THE CLASSICAL AND QUANTUM MECHANICAL PICTURES

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SUMMARY

A throughout understanding of the factors affecting spray flow in irrigation systems is important for developing appropriate conservation strategies. Resolving this problem involves both theoretical and experimental considerations.

Among the theoretical studies the classical mechanical approach, based on Newton's law, offers a useful tool to describe the trajectories of water droplets travelling from the sprinkler nozzle to the ground. Within this context, a mathematical model for irrigation sprinkler droplet ballistics has been presented and validated. Moreover, a new approach has been proposed, the so-called quantum mechanical picture based on the time-dependent Schrödinger equation and the wave function. This procedure leads to a new concept of quantum ballistics, in analogy to the well-established concept of classical trajectory, and represents a versatile tool for the description of the motion and of the dynamical properties of falling particles, as well as an exciting area of research in the years to come.

***Keywords**: sprinkler irrigation, spray flow, droplet ballistics, Lagrangian and quantum trajectories.*

INTRODUCTION

A quantitatively reliable description of water droplet trajectories in sprinkler irrigation practice is a challenging task. Resolving this complexity involves both theoretical and experimental considerations. For an analytical picture of the process, the mutual dependence of the parameters characterizing the phenomenon (such as: dimension of the droplet, air friction, wind velocity) needs to be identified and properly described by the hydro-dynamical equations representing water spray trajectories. The issue entails both experimental and theoretical studies. The aim of the former is to identify, and so to measure, the contribution of each parameter to the final result; the target of the second is to work out an exhaustive analytical framework of the process. Both experimental and theoretical attempts in this field have been brought forth recently, but still the word "end" is far from being given. With reference to the subject, two physical-mathematical approaches to water droplet ballistics are presented and analyzed in this work. The first application involves the classical mechanical picture of the water droplet trajectories; the second one is based on quantum mechanics and on the time-dependent Schrödinger equation.

DYNAMICS OF WATER DROPLET TRAJECTORIES

A full analytical description of how a droplet exiting from a sprinkler nozzle reaches to soil surface, undoubtedly, represents a great help in programming, managing and assessing the performance of sprinkler irrigation systems. The problem is essentially a physical-mathematical one as the mutual interactions of all the factors affecting the air path of a droplet make it difficult to devise a proper solution of the flight equations. These equations are the so-called hydro-dynamical equations. Now, in classical mechanics the state of a particle (droplet) is characterized by specifying the position $x(t)$ and the momentum $p(t)$ to an arbitrary accuracy. In quantum mechanics, position and momentum cannot simultaneously be specified to arbitrary accuracy (Dirac, 1931).

Classical Mechanical Picture

The classical mechanical approach to water droplet ballistics relies on mathematical models which describe a free falling droplet trajectory on the basis of the particle dynamics theory (Lagrangian trajectory).

Over the last 30 years, a significant modeling and data collection effort has been undertaken, mainly by the USDA Forest Service and its co-operators, to develop accurate, validated models (spray drift models) to predict the small droplet behavior (up to 10 µm or less) in both sprinkler irrigation practice and chemical spray aerial applications (Keller et al. 1990;Teske et al., 1998a,b).

The models are based on both the Lagrangian trajectory analysis of the spray material and Gaussian slanted-plume approach (Teske and Ice, 2002). Recent extensive field studies (Hewitt et al., 2002) and model validation efforts (Bird et al., 2002) confirmed the predictive capability of the Lagrangian computational procedure that constitutes the core of the spray drift classical mechanical models. An in-depth review of this issue can be found in Lorenzini (2004) and De Wrachien and Lorenzini (2006). These Authors proposed a set of easy-to-use parametric equations of the droplet flight, based on the classical hydrodynamical theory, which proved to fully match the kinematic results obtained by more complicated procedures.

The flow of a droplet from the sprinkler nozzle down to the ground is described by means of the Second Principle of dynamics: $\vec{F} = m\vec{a}$, where $\vec{F}$ is the total force in an N–particles system, acting on the droplet and equal to the vector sum of the weight of the droplet of mass m in kg diminished by its buoyancy force and of the friction force acting during the flight on the droplet of acceleration $\vec{a}$ in ms^{-2}. The friction factor f used in the model is that defined by Fanning (Bird et al., 1960). For a fluid flow surrounding a droplet it is given by:

(a) for Reynolds number $Re < 0.1$: $f = \frac{24}{Re}$

(b) for $2 < Re < 500$: $f = \frac{18.5}{Re^{0.6}}$

(c) for $500 < Re < 200000$: $f = 0.44$

Case (a) expresses the conditions of the laminar flow law; case (b) of an intermediate flow law, and case (c) of the turbulent flow law. Case (a), statistically speaking, is very unlikely to occur in sprinkler irrigation practice as, at the usual flow velocities, it would imply droplet diameters of an order of magnitude 0.1 μm, which is more typical with chemical spray application rather than with irrigation.

The hypotheses formulated are that: each droplet is generated exactly in correspondence to the nozzle outlet; the forces applied to the system are weight, buoyancy, friction; the droplet has a spherical shape; the volume of the droplet is invariant during the flight; the friction has the same direction of the droplet velocity but opposite sense for all the path; and there is no wind.

The parameters to be introduced are: the nozzle height h with respect to ground level; the droplet velocity v and the angle α, with respect to the horizontal direction of the jet.

If n is the mass of the droplet accounting for its buoyancy component and the friction parameter k in kgm^{-1} (given by $k = \frac{f\rho A}{2}$ where ρ is air density, depending on temperature, and A is the cross section in m^2 of the droplet) is the coefficient which defines the action of the friction force, then the final equations in the horizontal and vertical directions are:

$$m\ddot{x} = -k\dot{x}^2 \tag{1}$$

$$m\ddot{y} = -k\dot{y}^2 - ng \tag{2}$$

where $\dot{x}$, $\dot{y}$, $\ddot{x}$, $\ddot{y}$ are velocities in ms^{-1} and accelerations in ms^{-2} in the horizontal and vertical direction, respectively. The initial conditions are:

$$x(t=0) = 0 \tag{3}$$

$$\dot{x}(t=0) = v_{0x} \tag{4}$$

for the first equation and:

$$y(t=0)=h \tag{5}$$

$$\dot{y}(t=0)=v_{0y} \tag{6}$$

for the second one: where t is time; v_{0x}, v_{0y} represent the horizontal and vertical velocity components in ms^{-1}, respectively, at the entrance; and h is the nozzle height with respect to the ground, in m. Integrating the system of differential equations we obtain the full analytical solution of the problem in the form of parametric equations of position (x(t), y(t)), velocity ($\dot{x}$(t), $\dot{y}$(t)) and flight time.

The model, providing an exact solution, applies to every particular configuration of the system, i.e. for every droplet diameter, flow state, air temperature nozzle geometry, initial flow rate and velocity, in the hypotheses formulated. Attention, though, has to be drawn to the friction parameter k, as it is strongly affected by the flow state of the droplet. In fact it may happen (and it often does) that a droplet starts its path in a certain flow state modifying it along the way, so requiring a different value of k to be inserted in the model. Lorenzini (2002, 2004) showed that, apart from the smallest diameter droplet, all the cases fall in the turbulent flow law region in which the value for f is 0.44.

The validation of the procedure needs a quantitative approach to check how reliable the predictions are: this can be done introducing other Authors' data in the model. The works chosen for these comparison purposes are by Edling (1985) and Thompson et al. (1993). Among the case studies by these Authors, only those involving a no-wind condition were considered. Results are shown in Fig 1 to 7 in terms of travel distance and in table 1 in terms of time of flight.

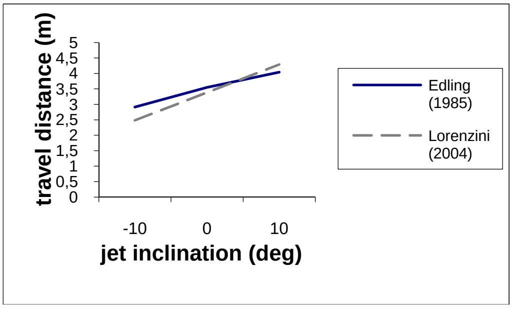

Figure 1 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004). Flow rate: $1.4x10^{-4}$ m^3s^{-1}; nozzle diameter: $3.96x10^{-3}$ m; air temperature 29.4°C; nozzle height: 1.22 m; droplet diameter: $1.5x10^{-3}$ m. (R^2=0.997)

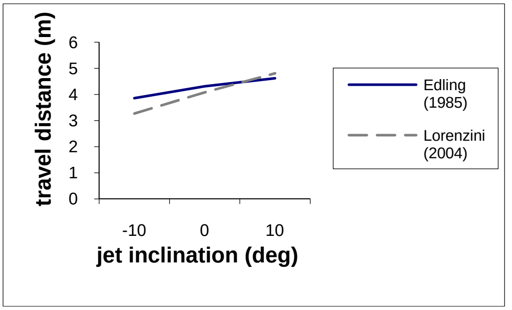

Figure 2 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004). Flow rate: 1.4×10^{-4} m^3s^{-1}; nozzle diameter: 3.96×10^{-3} m; air temperature 29.4°C; nozzle height: 2.44 m; droplet diameter: 1.5×10^{-3} m. (R^2=0.997)

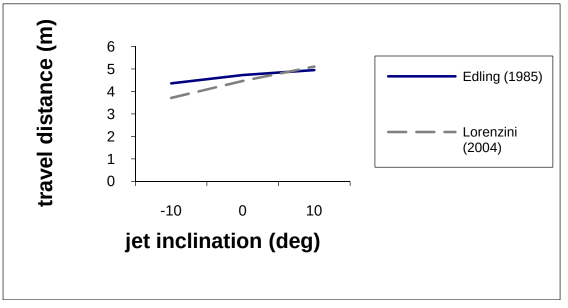

Figure 3 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004). Flow rate: 1.4×10^{-4} m^3s^{-1}; nozzle diameter: 3.96×10^{-3} m; air temperature 29.4°C; nozzle height: 3.66 m; droplet diameter: 1.5×10^{-3} m. (R^2=0.995)

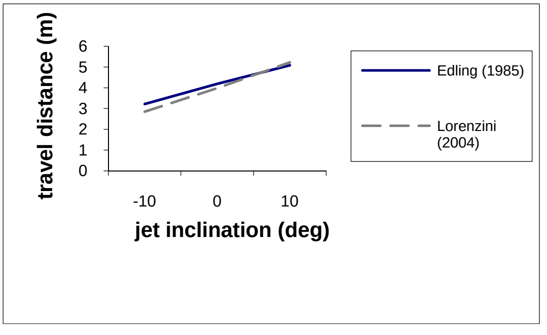

Figure 4 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004). Flow rate: 1.4×10^{-4} m^3s^{-1}; nozzle diameter: 3.96×10^{-3} m; air temperature 29.4°C; nozzle height: 1.22 m; droplet diameter: 2.5×10^{-3} m. (R^2=0.999)

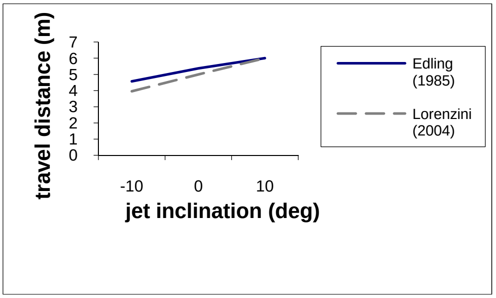

Figure 5 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004). Flow rate: 1.4×10^{-4} m^3s^{-1}; nozzle diameter: 3.96×10^{-3} m; air temperature 29.4°C; nozzle height: 2.44 m; droplet diameter: 2.5×10^{-3} m. (R^2=0.998)

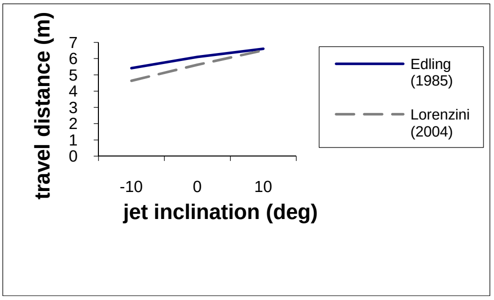

Figure 6 Travel distance of sprinkler droplets: Edling's (1985) data compared to Lorenzini's (2004). Flow rate: 1.4×10^{-4} m^3s^{-1}; nozzle diameter: 3.96×10^{-3} m; air temperature 29.4°C; nozzle height: 3.66 m; droplet diameter: 2.5×10^{-3} m. (R^2=0.998)

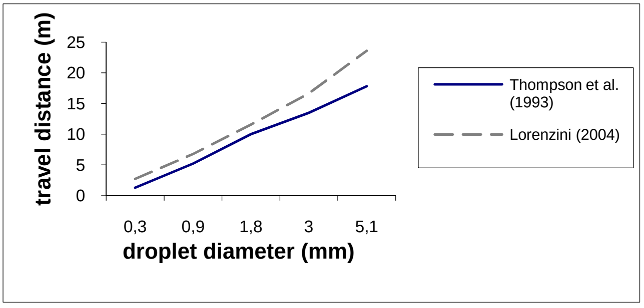

Figure 7 Travel distance of sprinkler droplets: Thompson et al (1993) data compared to Lorenzini's (2004). Flow rate: 5.5×10^{-4} m^3s^{-1}; nozzle diameter: 4.76×10^{-3} m; air temperature 38°C; jet inclination: 25°; nozzle height: 4.5 m. (R^2=0.994)

Table 1 Time of flight of sprinkler droplets: Thompson et al (1993) data compared to Lorenzini's (2004). Flow rate: 5.5 x 10^{-4} m^3s^{-1}; nozzle diameter: 4.76 x 10^{-3} m; air temperature 38°C; jet inclination: 25°; nozzle height: 4.5 m.

		Droplet diameter (m)			
		0.9 x 10^{-3}	1.8 x 10^{-3}	3.0 x 10^{-3}	5.1 x 10^{-3}
Time of flight (s)	*Thompson et al. (1993)*	1.54	1.63	1.75	1.84
	Lorenzini (2004)	1.35	1.73	2.00	2.26

Facing a comparative approach, it can be stated that the model here defined proves to be kinematically reliable in its predictions from a qualitative and quantitative points of view, particularly when droplets having a "not too small" diameter are considered. This, being the model defined by neglecting most of the parameters typically introduced in the others, can be considered as a first relevant result. The comparisons performed with the Thompson et al. (1993) data show that when the droplet gets close to a condition of the laminar flow law the model provides less accurate results. This is the limit to the model and it somehow defines the field of acceptability of the method. The model becomes weaker when moves away from the turbulent flow law because of the approximation used to define the value of k in the other two flow patterns. The dependence of the results on the flow state criterion can easily explain the different results obtained for the smallest droplets in the present work and in Thompson et al. (1993).

Quantum Fluid Mechanical Picture

The Quantum Mechanics (QM) of a many-particles system, as an irrigation spray flow, is based on the Time-Dependent Schrödinger Equation (TDSE) which involves the definition of a wave function $\psi(x,t)$ that gives the probability of finding a particle at the location x at the time t. Therefore, the Quantum Theory of Motion (QTM) needs the simultaneous presence of the "wave" and the "particle", as opposed to the conventional classical mechanical picture which defines the position x of the particle at a conventional time t.

In QM the wave motion is governed by the solution of the TDSE and the motion of a particle, guided by that wave for a given initial position, is characterized by a velocity defined as the gradient of the phase of the wave function. An assembly of initial positions will constitute an ensemble of particle motions (the so-called quantum trajectories or Bohmian trajectories) guided by the same wave, and the probability of finding the particle at a given point x and at a given time t is provided by the QM probability density (Holland, 2011).

The quantum trajectory method provides an efficient methodology for solving both stationary and time-evolving states and allows the development of both Lagrangian and Eulerian techniques (Goldstein et al., 2011). In QM a particle trajectory $Q(t)$ can always be written in form of the Newton's law (Second Principle of Dynamics):

$$m \cdot \frac{d^2Q(t)}{dt^2} = F(t) \tag{7}$$

where *m* is the mass of the particle.

In a many-particle (N) system, and with reference to the k-th particle, equation (7) can be written as:

$$m_k \cdot \frac{d^2Q_k(t)}{dt^2} = -\nabla_k\left(V + V_{qu}^{\psi_t}\right) \cdot Q(t) \tag{8}$$

where $\nabla_k = \left(\frac{\partial}{\partial x_k}, \frac{\partial}{\partial y_k}, \frac{\partial}{\partial z_k}\right)$ is the derivative with respect to the coordinates of the k-th particle; V is a potential function; $V_{qu}^{\psi_t}$ is a function called the quantum potential:

$$V_{qu}^{\psi_t} = -\sum_{j=1}^{N} \frac{\hbar^2}{2 \cdot m_j} \cdot \frac{\nabla_j^2|\psi|}{|\psi|} \tag{9}$$

with $j: 1 \leq j < k \leq N$, $\hbar = 1.0545 \cdot 10^{-27}\ erg \cdot s$ is the Planck's constant.

For comparison, a classical particle would move according to:

$$m_k \cdot \frac{d^2Q_k(t)}{dt^2} = -\nabla_k V \cdot Q(t) \tag{10}$$

A Bohmian trajectory is also a solution to classical mechanics if we add a suitable time-dependent term $V_{qu}^{\psi_t}$ to the potential function V (Lopreore and Wyatt, 1999).

The regime in which quantum trajectories agree with classical trajectories is characterized by the condition that the gradient of the quantum potential vanishes or, at least, is small. This concept allowed transforming the TDSE into a pair of hydro-dynamical equations, consisting of the continuity equation and an Euler type equation, giving birth to the so-called Quantum Fluid Dynamics (QFD) (Wyatt, 2005; Ghosh, 2011).

For an *N*-particle system, as an irrigation spray flow, with its particles in the field of their mutual repulsion, as well as to vector potentials, the quantum mechanical description of a single particle moving in a scalar potential $V(\vec{x}, t)$ is based on the TDSE given by:

$$D^2\nabla^2\psi(\vec{x}, t) - \frac{1}{2} \cdot m \cdot V(\vec{x}, t) \cdot \psi(\vec{x}, t) = -i \cdot D \cdot \left(\frac{\partial}{\partial t}\right) \cdot \psi(\vec{x}, t) \tag{11}$$

where:

$$D = \frac{\hbar}{2 \cdot m} \tag{12}$$

is the diffusion coefficient;

$$\psi(\vec{x},t) = R(\vec{x},t) \cdot exp[S(\vec{x},t)] \tag{13}$$

with $R(\vec{x},t)$ and $S(\vec{x},t)$ the amplitude and the phase of the wave function respectively.

Equation (11) can be split into two fluid dynamical equations, given by the continuity equation:

$$\frac{\partial}{\partial t}\rho(\vec{x},t) + \nabla[\rho(\vec{x},t) \cdot \vec{v}(\vec{x},t)] = 0 \tag{14}$$

And the Euler equation:

$$\frac{d}{dt}\vec{v}(\vec{x},t) \equiv \left[\frac{\partial}{\partial t} + \vec{v}(\vec{x},t) \cdot \nabla\right]\vec{v}(\vec{x},t) = -\frac{1}{m} \cdot \nabla[V(\vec{x},t) + Q(\vec{x},t)] \tag{15}$$

where $\rho(\vec{x},t) = R^2(\vec{x},t)$ is the fluid density and $V(\vec{x},t) = 2 \cdot D \cdot \nabla S(\vec{x},t)$ the velocity field.

Equations (14) and (15) are known as Quantum Fluid Dynamics (QFD) equations. The equations of QFD describe the motion of a fluid particle in the force field of the classical potential $V(\vec{x},t)$ augmented by the force arising from the quantum potential $Q(\vec{x},t)$ given by:

$$Q(\vec{x},t) = \frac{-2 \cdot m \cdot D^2 \cdot \nabla^2 \mathrm{R}(\vec{x},t)}{\mathrm{R}(\vec{x},t)} \tag{16}$$

Equations (11), (14) and (15) can easily be extended for describing trajectories of clusters of particles within a single-particle framework (Wyatt, 2005). This approach provides an unified computational method for including both classical and quantum mechanical features in a particle dynamical frame.

Several methods for the numerical solution of the quantum hydrodynamic equations of particle-motion are available. These methodologies can be divided into two classes, those based on “numerical approximations” and those based on “dynamical approximations” (Kendrick, 2011).

The quantum trajectory based approach is computationally attractive due to its similarity with the standards of the classical particle dynamic theory, i.e. Newton’s equation of motion with forces proportional to the gradient of an interactional-particle potential.

Much progress has been made in recent years in developing computational methods for solving the quantum hydrodynamic equations. The challenges associated with the quantum mechanical approach will no doubt continue to inspire significant progress in the years to come.

The Scale Relatively Theory (ScR) reformulates QM principles by considering a particle in the joint space-time domain and applies to both the microscopical and macroscopical levels (Nottale et al., 1992). Whitin this ground, Hermann was the first who applied the equations of the ScR theory to describe trajectories of free-particles in an infinite one-dimensional domain utilizing a probability density function based on the TDSE (Hermann, 1997).

For a particle in an infinite one-dimensional domain, the equation of motion can be represented by the complex Newton equation:

$$\nabla u = m \cdot \frac{ð}{dt} \boldsymbol{V} \tag{17}$$

where u is a scalar potential and $\boldsymbol{V}$ is a complex velocity. Equation (17) can be separated into real and imaginary components:

$$\begin{cases} -D \cdot \Delta U - (\mathrm{U} \cdot \nabla) U = -\nabla u \\ \frac{\partial}{dt} U = 0 \end{cases} \tag{18}$$

where U is the imaginary part of complex velocity and D is the coefficient previously defined. The first equation of the system (18) can be written as (Al-Rashid et al., 2011):

$$\frac{d}{dx} U(x) = -\frac{m}{\hbar} \cdot U^2(x) + \frac{2}{\hbar} \cdot (u(x) - E) \tag{19}$$

Equation (19) assumes the form of Riccati equation (Reid, 1972) with $E = m \cdot c_1$ and c_1 a constant of integration.

Transforming equation (18) into a second order differential equation we obtain:

$$\frac{d^2}{dx^2} y(x) - \frac{2 \cdot m}{\hbar} \cdot (u(x) - E) \cdot y(x) = 0 \tag{20}$$

where $y(x)$ is an arbitrary function of x.

Equation (20) describes the behavior of a quantum particle in a one-dimensional space-time domain without explicitly using the TDSE and represents a new simplified tool for analyzing trajectories of both free and in a force field particles . Different computer programs to numerically simulate the trajectory of a quantum particle, within the context of the ScR theory,are nowadays available (Hermann, 1997). Comparisons of these results with the correspondent outcomes obtained from conventional QM show a very good agreement.

This agreement could be further improved by optimizing the parameters used in the numerical simulations and represents a sound example on how the ScR theory can accurately describe quantum mechanical trajectories without applying the TDSE.

CONCLUDING REMARKS

A thorough understanding of the factors affecting water droplet trajectories in sprinkler irrigation systems is important for developing appropriate water conservation strategies. To properly tackle this problem relevant theoretical and experimental studies have been carried out during the second half of the 20^{th} Century.

Among the analytical studies, the classical mechanical approach, based on the Newton's law and on the Lagrangian trajectory theory, offers a well-established tool to assess jet flow and describe the event of a droplet travelling from the sprinkler nozzle to the ground.

Within this concept, a new mathematical model for irrigation sprinkler droplet ballistics, based on a simplified dynamic approach to the phenomenon, has been presented and validated. This tool can be considered as an indicator of the system performance and has proved to fully match the kinematic results obtained by more complicate procedures.

Finally, a new approach has been proposed and highlighted, the so-called QM picture, based on the TDSE and on the wave function. The TDSE can always be transformed in a pair of Quantum Fluid Dynamics (QFD) equations, consisting of the continuity and Euler type equations. This procedure leads to the new concept of quantum ballistics in analogy to the well-established concept of a classical trajectory. For a many-particle system, as spray flow, the QM approach represents a versatile tool for the description of the motion and of the dynamical properties of particles and will represent an exciting area of research in the years to come.

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Original scientific paper

A COMPARISON REGARDING MODELS USED IN AGRICULTURAL DRAINAGE SYSTEMS DESIGN IN BRAZIL AND ROMANIA

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SUMMARY

Drainage systems for agricultural purposes are systems that make easier the process of draining water from the field so that agriculture can benefit from the effects of continuous reduction of the degree of saturation with water and / or reduce the presence of toxic soluble substances. The main natural factors which influence the excess soil water are: climatic regime, topography and hydrological regime of the territory. They are associated with geological, lithological, soil and hydrogeological ones, which together cause flood phenomena of stagnation and excess water on the land of plains and plateaus on the plane.

The multitude and variability of situations with humidity excess which can appear resulted in the use of numerous computation methods and programs which offer solutions with different levels of efficiency. Manual, classical, methods were replaced by specialized software. These software’s are presenting a small risk regarding the potential errors and there are able to present detailed prognosis of the studied phenomenon.

Key words: *DrenVSubIr, SISDRENA, drainage systems design*

INTRODUCTION

Broadly speaking, the objective of subsurface drainage systems is to control the water-table in the soil in order to create proper soil water conditions for crop growth and farm operations. The preparation of a subsurface drainage plan involves the determination of an optimal combination of variables which can be categorized in the following groups: system variables (types of drains, structures and outfalls; alignments, spacing, depths, capacities; materials and construction methods etc.), land use variables (crops and crop rotations, farming systems, farming practices, etc), environmental variables and management variables.

In the design process of a subsurface drainage system, the following main variables must be defined: type and layout of the system, discharge capacity of the system (q), watertable depths to be maintained in the field relative to the soil surface (h), the field drainage base depth (D) i.e., the installation depth of the pipe drains or the waterlevel to be maintained in the ditches (h_{drain}), and spacing of the field drains (L).

Drain spacing formulae may be categorized as either steady state formulae or non-steady state formulae. Steady state formulae are based upon the assumption that a steady constant flow occurs through the soil to the drains. Discharge equals recharge and the water-table head (h) is constant. In the non-steady state formulae all these parameters vary in time and the water-table fluctuates during the drainage process.

Non-steady state drainage formulae enable the water-table behavior over a certain period to be simulated on the basis of the (infiltrated) rainfall and (actual) evapotranspiration data for that period. Water-table hydrographs may thus be developed using the historical daily weather data for a range of basic design criteria. Several computer models as DRAINMOD, SWAP or SISDRENA are especially suitable for such water table simulations.

The most prominent drainage model that is used in North America is DRAINMOD (Skaggs,1981). This model has been used in all regions of the United States, and in many other countries, and is a truly effective method for the design of drainage systems (Skaggs, 1990). Input requirements for the model includes, among other things, the distance between drains, which, considering the technical literature from Romania, is the main element in the process design of a drainage system.

MATERIALS AND METHODS

Even Romanian researchers developed different methods for an efficient design of agricultural drainage systems, unfortunately, these methods were not transposed in computer programs and their resolving processes suppose long time and predisposition to errors.

Only in 2007 appeared a new program, DrenVSubIr, with a friendly interface, program which calculate the distance between drains and also verify the possibilities for applying the sub-irrigation. DrenVSubIR application is developed in Borland Delphi Pascal v7.0 programming system and is created for calculating sizes specific to drainage system such as: determination of the distance between drains with the verifying operation in sub-irrigation.

DrenVSubIR application consists in three modules: “Drainage - Ernst Equation - David” module (for the calculus of resistance coefficient at water entry in drain tube, with and without filter); “Verifying Sub-Irrigation – David Equation” module (for the drainage verifying operation calculus in sub-irrigation) and “Drainage: Technical-Economic Calculation” module (for the specific investment calculus and for establishing the optimum technical-economic solution of drainage). DrenVSubIr application is based on Ernst equation fulfilled with the additional term ζ_{if} proposed by I. David.

$$h = \frac{q \cdot D_v}{K} + \frac{q \cdot L^2}{8 \cdot K \cdot T_e} + \frac{q \cdot L}{K} \cdot \ln \frac{\alpha \cdot D_0}{U} + \frac{q \cdot L}{K} \cdot \zeta_{if}$$

where ζ_{if} (represents the effect of head losses at water entrance in drain due to the filtering material) can be analytically calculated with the following relation:

$$\zeta_{if} = \alpha \cdot \left[\ln \frac{1}{\sin \frac{nb}{2d_0}} + \frac{1-\chi}{2\chi} \cdot \ln \left(A_1 + \sqrt{A_1^2 + 1} \right) \cdot \left(A_2 + \sqrt{A_2^2 + 1} \right) \right] + \beta \cdot \left[\ln \frac{1}{\sin \frac{\ell}{2B}} + \frac{1-\chi}{2\chi} \cdot \ln \left(B_1 + \sqrt{B_1^2 + 1} \right) \cdot \left(B_2 + \sqrt{B_2^2 + 1} \right) \right]$$

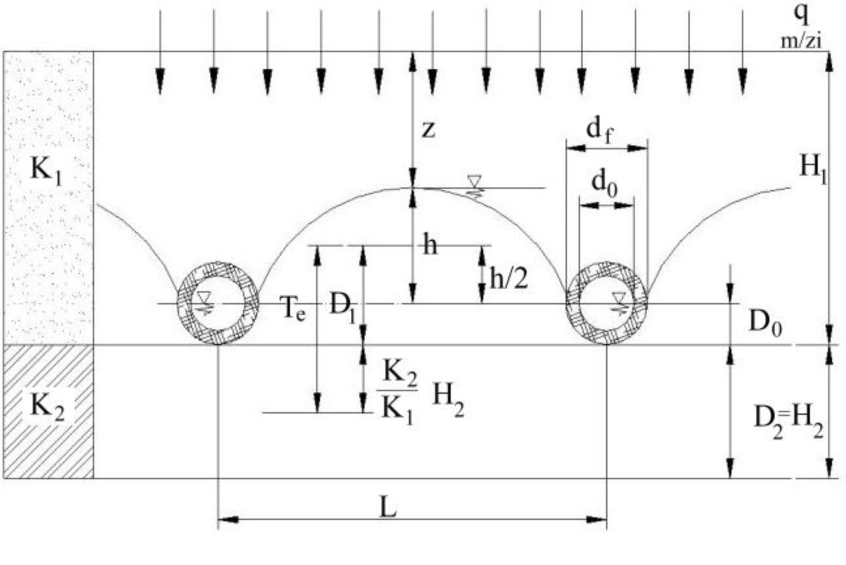

Figure 1 Ernst equation graphic scheme

SISDRENA was coded in Visual Basic 6.0 at the Department of Biosystems Engineering (LEB), "Luiz de Queiroz" College of Agriculture (ESALQ/USP), Piracicaba, SP, Brazil. It is a one dimensional model that accounts for the major components that affect the water balance in a section of homogeneous soil with unit surface area, located midway between two parallel drains and extending from the impervious layer to the soil surface. These components are: precipitation, runoff, infiltration, percolation to groundwater, upstream from the groundwater level to the root zone, evapotranspiration, drainage and vertical "seepage" (figure 2).

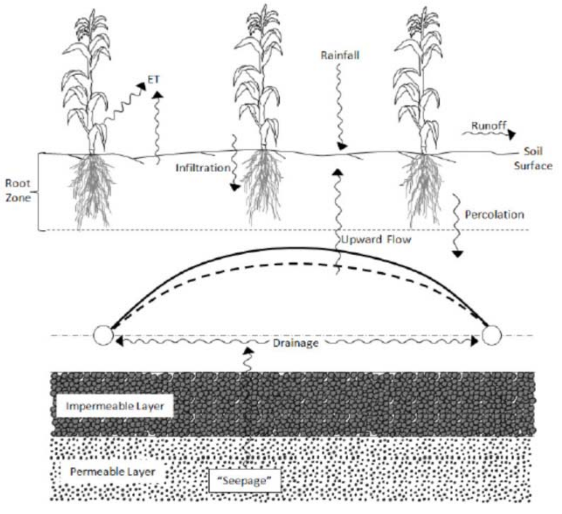

Figure 2 Scheme of the main flow components considered by the model

The SISDRENA model uses historical daily precipitation and potential evapotranspiration data, soil physical properties, crop characteristics, and drainage system lay-out, in the simulation of runoff, water table position, drain discharge, actual evapotranspiration, and root-zone soil water storage. In the model, the position of the water was estimated by de Zeeuw-Hellinga equation. The model was developed to address some limitations of its predecessor, the SIMDRENO model. Improvements include a more precise way for characterizing the effect of upflux on water table movement and runoff estimation.

The required input parameters, and output parameters provided by SISDRENA are given in Tables 1 and 2, respectively.

Table 1 Required input parameters for SISDRENA

Total daily precipitation, mm/day
Daily potential evapotranspiration, mm/day
Saturated hydraulic conductivity of saturated soil, m/day
Depth to impervious layer, m
Values of drain spacing to be submitted for evaluation, m
Daily upward flow by vertical seepage (optional), mm/day
Drain depth, m
Effective radius of the drain, m
Soil water retention curve
Planting and harvesting dates of the crop
Variation of the effective root system depth throughout the year, m
Daily factors for the crop sensitivity to excess and lack of water
Starting groundwater level above the drains m
Starting volumetric soil water content

Table 2 SISDRENA output parameters

Daily overland runoff, mm/day
Daily infiltration, mm/day
Daily groundwater level, m
Daily drain flow mm/day
Daily water storage in the root zone, mm
Daily actual evapotranspiration; mm/day
System evaluation parameters
Most economical drain spacing

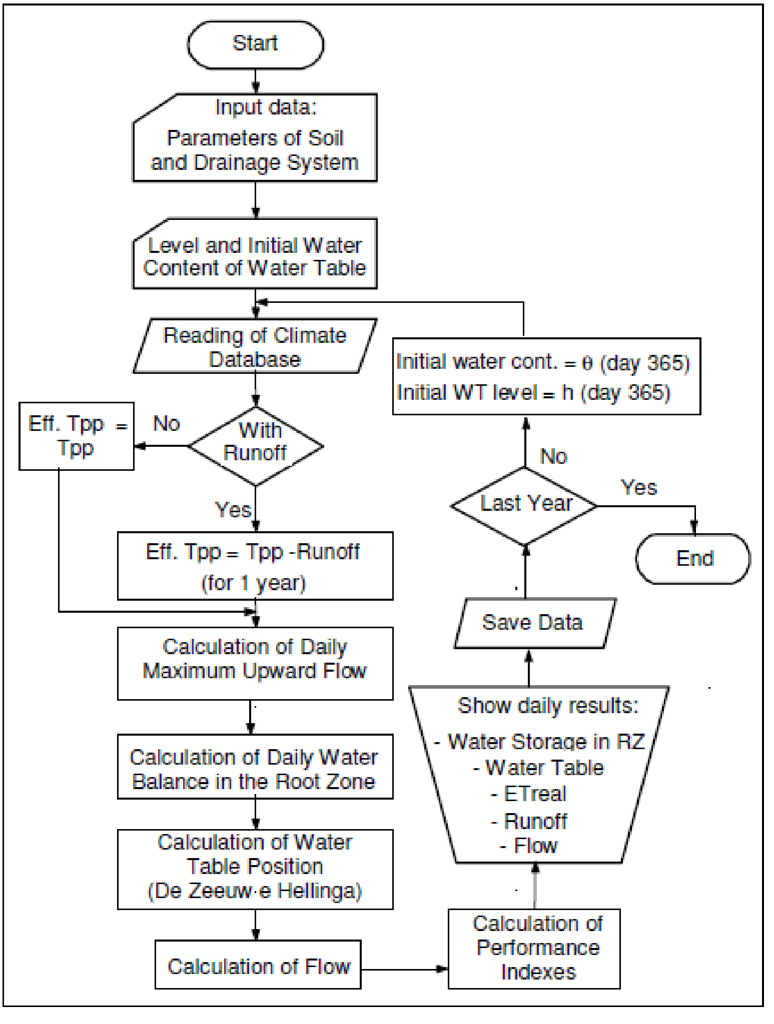

Figure 3 Flowchart of SISDRENA model

RESULTS

The studies were realized for Faget, an area located in western part of Romania, Timis County. We used a drain of 5 cm diameter with and without filtering material (Filtex δ =0.6 cm, K_{soil} = 0.5m/day, h = 0.6m, depth of impermeable layer = 3m, drain depths = 1.4 m) and we calculate the distance between drains by using two programs: DrenVSubIr (Ernst formula) and Espadren (Ernst formula). Espadren doesnt consider the head losses at water entrance in drains.

We obtained the following results:

Table 3

	DrenVSubIr (without filter)	DrenVSubIr (with filter)	Espadren (without filter)
L	16.61 m	22.94 m	20.27 m

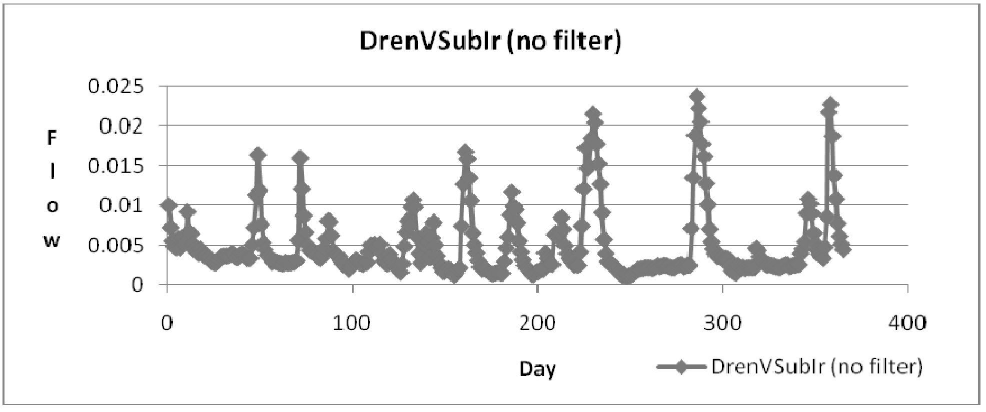

Figure 4 Discharged flow variation (SISDRENA program)

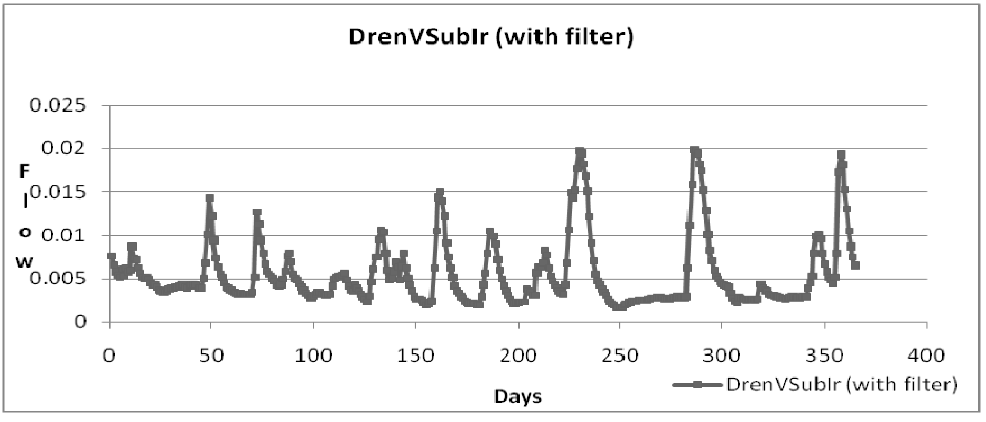

Figure 5 Discharged flow variation (SISDRENA program)

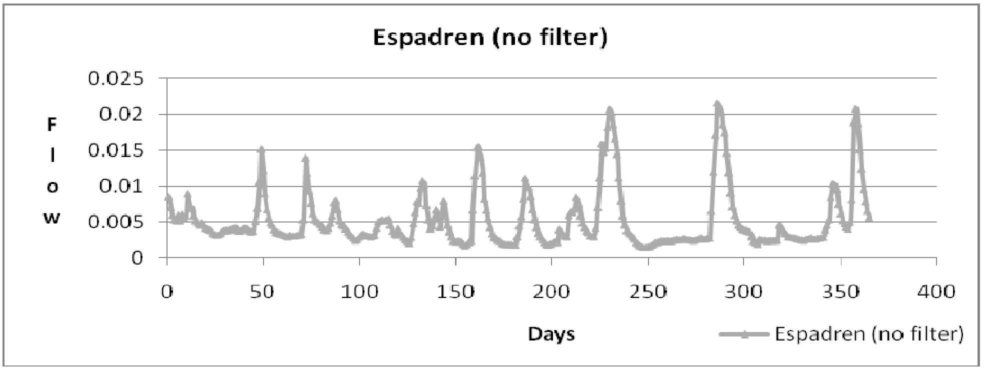

Figure 6 Discharged flow variation (SISDRENA program)

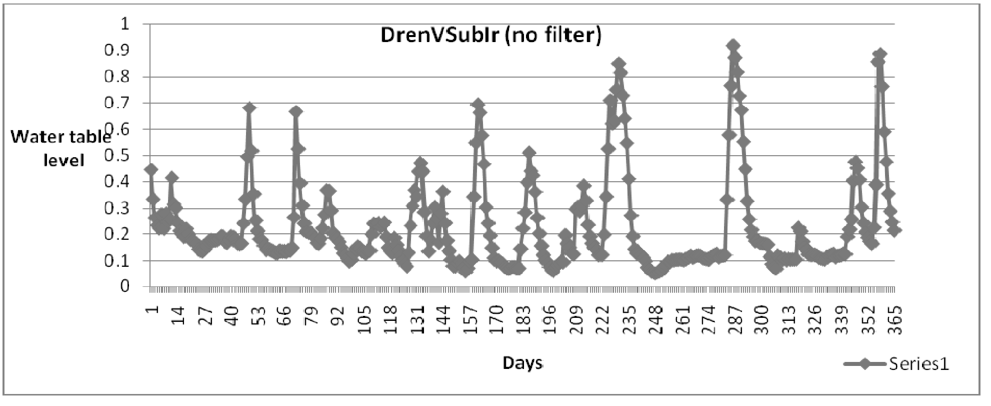

Figure 7 Water-table variation (SISDRENA program)

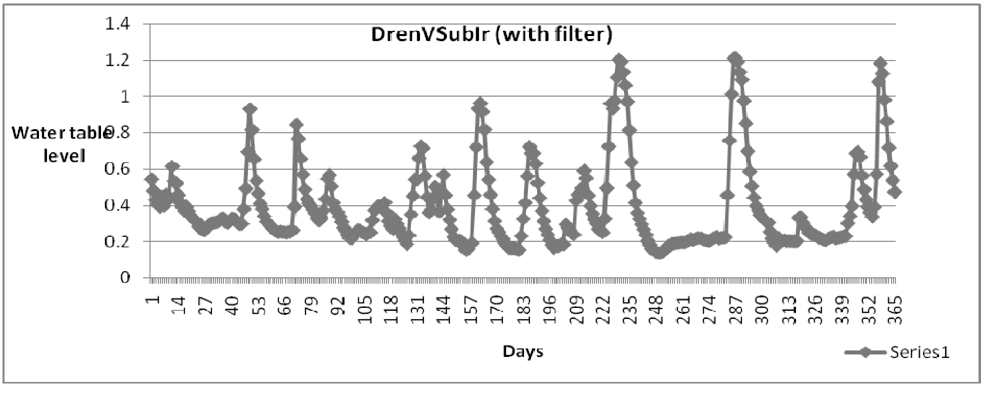

Figure 8 Water-table variation (SISDRENA program)

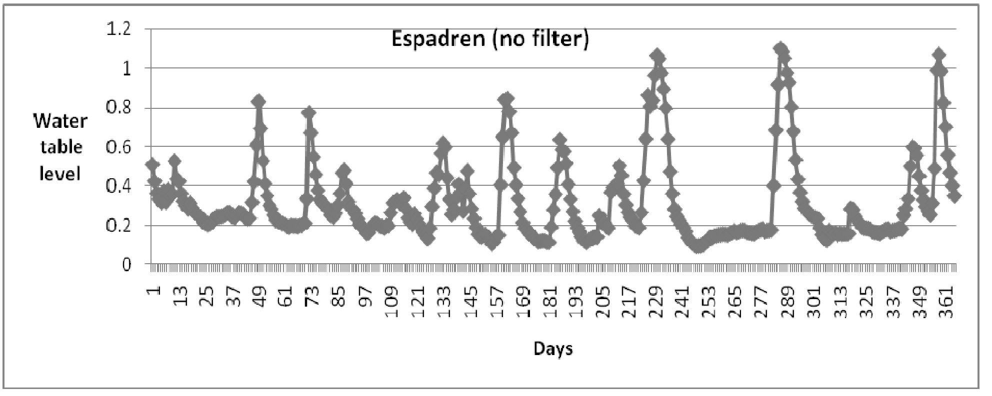

Figure 9 Water-table variation (SISDRENA program)

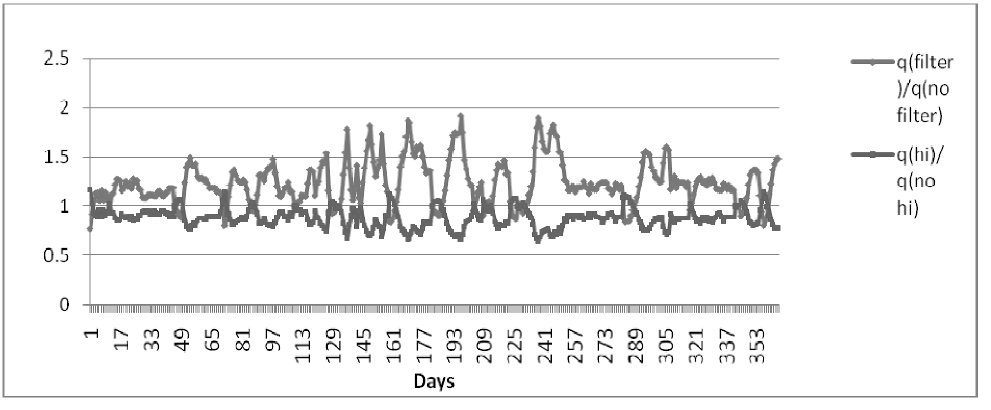

Figure 10 Impact of filtering material and of entrance head losses on discharged flow variation

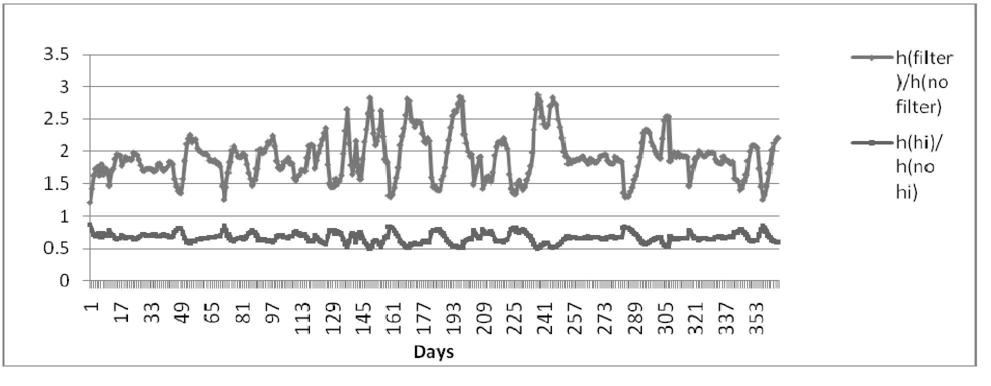

Figure 11 Impact of filtering material and of entrance head losses on water-table variation

DISCUSSION AND CONCLUSIONS

According to Romanian technical literature, the main element in designing a subsurface drainage system is represented by a correct calculation of distance between drain. The main researches were focused on this direction while in other countries (Western Europe, USA, Asia and South America), valuable researches were orientated to water-table variation and on discharged flow.

The multitude and variability of situations with humidity excess which can appear resulted in the use of numerous computation methods and programs which offer solutions with different levels of efficiency. Manual, classical, methods were replaced by specialized software. These software's are presenting a small risk regarding the potential errors and there are able to present detailed prognosis of the studied phenomenon.

The most prominent drainage model that is used in North America is DRAINMOD (Skaggs, 1981). This model has been used in all regions of the United States, and in many other countries, and is considered to be a truly effective method for the design of drainage systems (Skaggs, 1990). In other countries were developed similar models as: SISDRENA, DRENAFEM etc., models which proved that can compete with DRAINMOD and can be used efficiently in researches.

Input requirements for the model includes, among other things, the distance between drains. This element is very important to be determined correctly.

Some models developed so far for the determination of distance between drains didn't consider in their procedures the presence (or not) of filtering materials while other models didn't consider the head losses at water entrance in drains. These two factors can cause appreciable errors in drainage hydraulic design. In terms of filter material, the most important characteristic, with impact in designing distance between drains, is the thickness of the filtering material and not the initial permeability coefficient or permeability coefficient for filtering material after silting. The lack of considering these two factors, can lead to differences (in terms of distance between drains) of about 25% to 35% which will have a significant impact on discharged flow and on water-table variation.

It this idea, it is very important to improve the existing models in order to increase their complexity and the elements considered in calculations for a better hydraulic design of drainage arrangements. The authors will continue to analyze different models, to compare their results and to propose efficient solutions for an effective design of drainage systems.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

A COMPARISON OF THE HEAD LOSSES VALUES FOR BIHOR COUNTY'S DRAINAGE SYSTEMS USING THE RESULTS OBTAINED WITH DRENVSUBIR AND ESPADREN PROGRAMS

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SUMMARY

An efficient agriculture, taking in consideration the climatic conditions existent in Romania, can be practiced only with the support of efficient land reclamation and improvement systems. The land drainage systems are playing an important role in achieving the desired targets. The paper will present comparisons between the results obtained with DrenVSubIr and Espadren in computing the head losses (horizontal, vertical, radial and at entrance in drain) for some areas characterized by humidity excess from Bihor County.

***Key words**: soil humidity excess, drainage, head losses, DrenVSubIr, EnDrain*

INTRODUCTION

Romania's territory is under the influence of 3 hazard types (geomorphologic, hydrologic and climatic) with direct influence upon soil humidity. Soil humidity excess affects in Romania more than 8.5 million hectares (4 million hectares affected by temporary humidity excess from precipitations, almost 2 million hectares with permanent humidity excess caused by high water-table level, and about 2.5 million hectares with humidity excess from water courses infiltrations or caused by flooding) from which about 52% requests direct measures of drainage. In 2004, the surface arranged with drainage works and which were under the authority of National Administration of Land Reclamation and Improvement covered 3.085.245 ha, from these 1.463.927 ha were with water evacuation by pumping stations and the other 1.621.318 ha evacuate the water gravitational.

Humidity excess in Bihor County is related to floods and high or long-term rainfall and appears at the surface of the plain, on large areas of low and intermediate plain and in small patches of high plains. The causes of excess moisture are the following: the presence of clay lenses near the surface, heavy textured soils (clayey B horizon), groundwater flux at 0.5 – 2m, river slope less than 1 ‰ and due to rainy periods.

Waters from precipitation are maintained, often as an over-phreatic cloth, which sometimes merges with the water table resulting in marshes and ponds with specific soils with hydrophilic vegetation. Regarding groundwater itself, its presence is noted above the superficial layer waterproof, groundwater regime depending on climatic conditions largely.

The fields with permanent humidity excess are covering a total surface of 148.983 ha from which 89.390 ha are arable lands. Other 43.234 ha are soils affected by water erosion. The soils with humidity excess were localized by Bihor County Office for Soils and Agro-chemical Studies in the following areas: Cefa, Avram Iancu, Hidişelul de Sus, Călacea, Tarcea, etc.

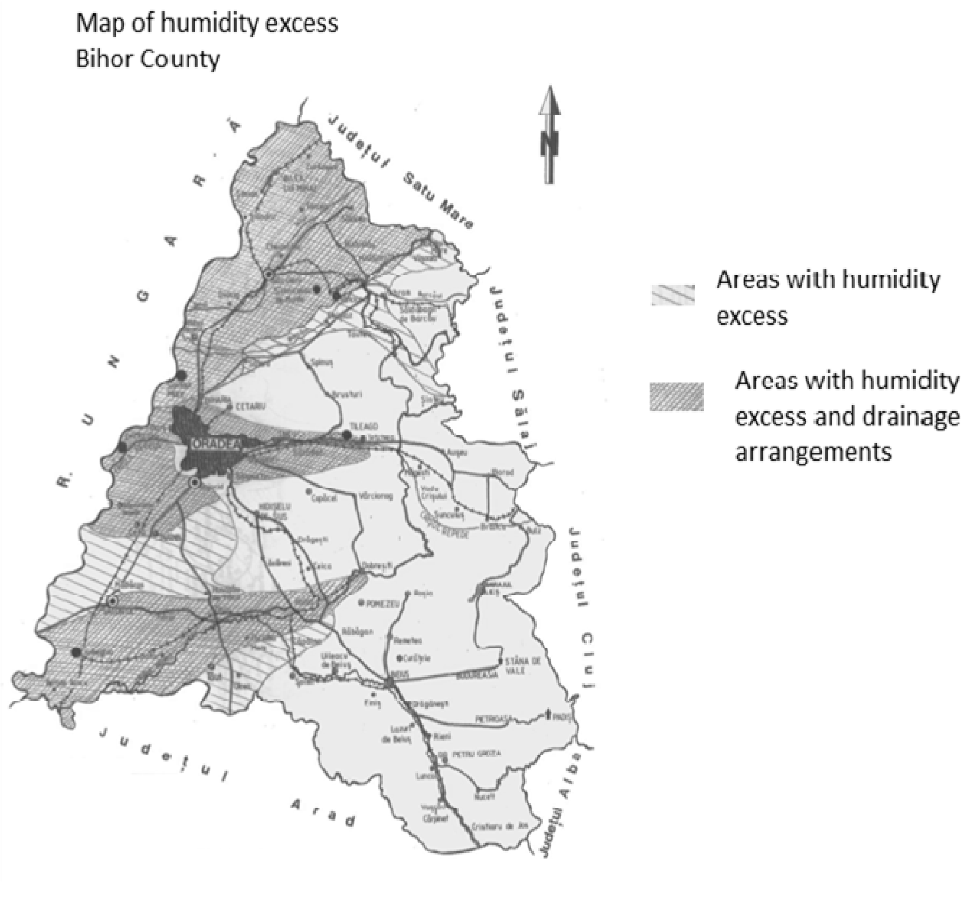

Figure 1 Map of humidity excess – Bihor County, Romania

MATERIALS AND METHODS

The multitude and variability of situations with humidity excess which can appear resulted in the use of numerous computation methods and programs which offer solutions with different levels of efficiency. Manual, classical, methods were replaced by specialized software. These software's are presenting a small risk regarding the potential errors and there are able to present detailed prognosis of the studied phenomenon.

Each of these programs analyze the humidity excess but from different points of view and by using different parameters. The authors selected for this paper the newest Romanian application in drainage design domain, DrenVSubIr, and one program from Costa Rica which has the necessary features in order to be able to compare the results.

DrenVSubIr represents the newest Romanian application used in drainage systems design and it was realized by a group of researchers from "Politehnica" University of Timisoara, Romania and the University from Oradea, Romania. This application was developed in Borland Delphi Pascal 7.0 and is intended to compute indicators characteristic for drainage systems as it is the distance between drains including the verification for sub-irrigation. The procedure designated for computing the distances between drains is based on Ernst formula and on the experimental drainage studies realized in the "Politehnica" University laboratory, studies which were carried according to the "Politehnica" University methodology for the main soils with humidity excess from western Romania.

Espadren is an application developed in Costa Rica for simplifying the computation of distances between drains using steady-state equations (Donnan, Hooghoudt, Dagan, Ernst) but also non steady-state equations (Glover-Dumm and Jenab) for open channels and buried drains. Espadren was realized using Visual Basic environment.

For this paper, were used the following materials: PVC drain tube (5 cm, 6.5 cm and 8 cm diameter) and PVC drain tube with Filtex as filtering material (0.6 cm thick).

The flow towards a subsurface drain, according to Ernst, (Érnst, 1954) can be divided in a vertical flow, a horizontal flow, a radial flow and an entry into it. The total loss of head (h_t) will be the sum of all differences presented in the following picture and expressed by vertical head loss (h_v), horizontal head loss (h_h), radial head loss (h_r) and entrance head loss (h_e).

The total head loss according to Ernst is:

$$h_t = h_v + h_h + h_r + h_e$$

One assumption used in drainage design is that of an "ideal drain", without entrance resistance, whereby the drain can be considered as an equipotential. Entrance resistance was neglected by many authors because they considered that the drain surround (envelope material and loosened soil in the trench) has a very high hydraulic conductivity compared to undisturbed soil. Practical experience has shown that this cannot always be taken for granted. For a rational designing of drainage systems is required the completion of the drainage calculation formulas for ideal drains with an additional term which takes into account the head losses from the drain-filter complex. The formula proposed by I. David (Romania) includes the terms proposed by Ernst and is fulfilled with the additional term ζ_{if}

$$h = \frac{q \cdot D_v}{K} + \frac{q \cdot L^2}{8 \cdot K \cdot T_e} + \frac{q \cdot L}{K} \cdot \ln \frac{\alpha \cdot D_0}{U} + \frac{q \cdot L}{K} \cdot \zeta_{if}$$

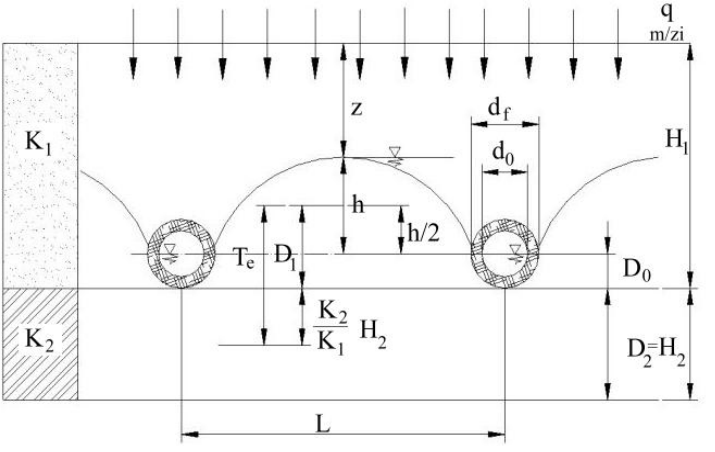

Figure 2 Ernst equation graphic schemes

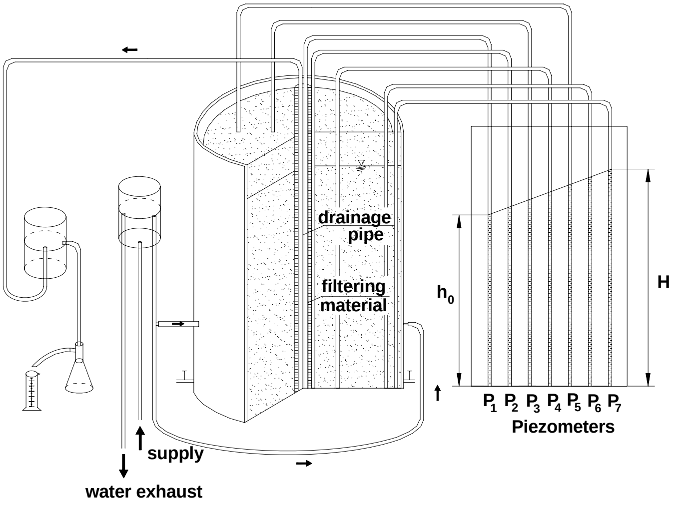

Figure 3

In the drainage laboratory of “Politehnica” University of Timisoara, Romania, were determined the hydraulic resistance coefficient of water entering the drainage pipe without filtering material (ζ_i) and of water entering the drainage pipes plus filtering material (ζ_{if}) being used an experimental stand having a vertical drainage pipe (fig. 3).

In order to establish the silting level, during time, of the drainage pipe (with filtering material), it was necessary to determine the initial permeability coefficient (before silting) for filtering materials (K_{fo}) by using a Darcy’s stand.

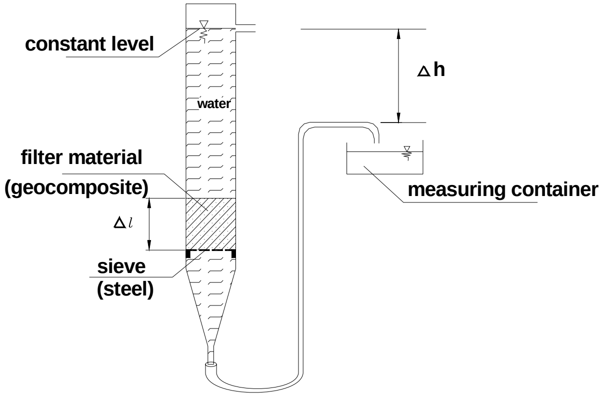

Figure 4

The silting level of drainage pipe with various filtering materials in contact with the drained was established on an experimental stand having the drainage pipe horizontal.

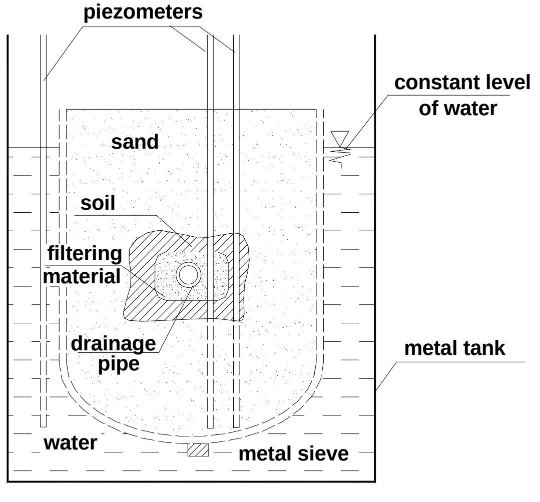

Figure 5

Having the values of permeability coefficient for filtering material after silting (K_{fc}), the author calculate the value of the hydraulic resistance coefficient of water entering the drainage pipe with filtering material (ζ_{if}), coefficient which allowed he author to calculate the distance between the drainage pipe lines (L) as well as all the 4 types of head losses by using Ernst-David formula.

For this paper were analyzed two areas (Cheresig and Ciumeghiu), each of them being affected by humidity excess.

RESULTS

In the next tables are presented the results obtained with the DrenVSubIr and Espadren programs.

Table 1 Distance between drains calculated for Cheresig area (K_{soil} = 0.05 m/day)

	DrenVSubIr (without filter)	DrenVSubIr (with filter)	Espadren
d = 0.05 m	L = 2.6 m	L = 6.37 m	L = 3.7 m
d = 0.065 m	L = 2.63 m	L = 6.45 m	L = 3.96 m
d = 0.08 m	L = 2.53 m	L = 6.44 m	L = 4.2 m

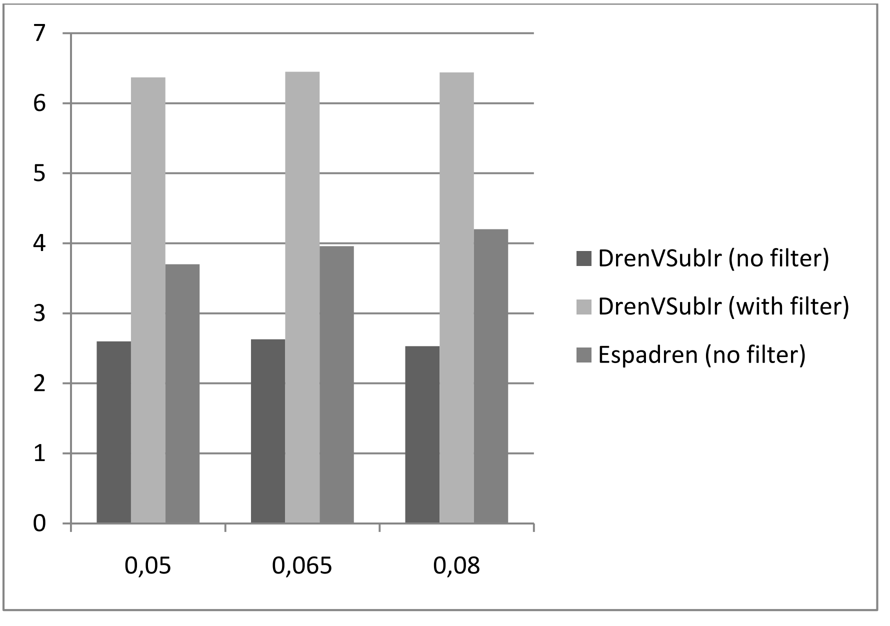

Figure 6 Distance between drains calculated for Cheresig area (K_{soil} = 0.05 m/day)

Table 2 Values of different head losses calculated for Cheresig area

	DrenVSubIr (without filter)	DrenVSubIr (with filter)	Espadren
d = 0.05 m	h_v = 0.084	h_v = 0.084	h_v = 0.084
	h_o = 0.062	h_o = 0.374	h_o = 0.126
	h_r = 0.242	h_r = 0.532	h_r = 0.39
	h_i = 0.212	h_i = - 0.39	
d = 0.065 m	h_v = 0.084	h_v = 0.084	h_v = 0.084
	h_o = 0.064	h_o = 0.383	h_o = 0.145
	h_r = 0.227	h_r = 0.506	h_r = 0.371
	h_i = 0.226	h_i = - 0.374	
d = 0.08 m	h_v = 0.084	h_v = 0.084	h_v = 0.084
	h_o = 0.059	h_o = 0.382	h_o = 0.162
	h_r = 0.209	h_r = 0.491	h_r = 0.354
	h_i = 0.247	h_i = - 0.357	

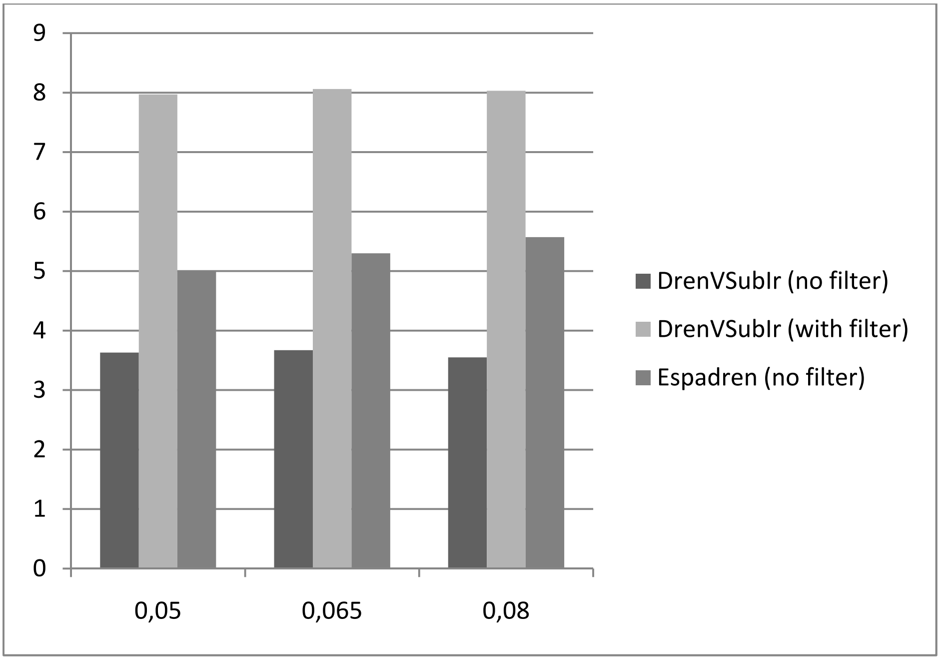

Figure 7 Distance between drains calculated for Ciumeghiu area (K_{soil} = 0.07 m/day)

Table 3 Distance between drains calculated for Ciumeghiu area (K_{soil} = 0.07 m/day)

	DrenVSubIr (without filter)	DrenVSubIr (with filter)	Espadren
d = 0.05 m	L = 3.63 m	L = 7.97 m	L = 5 m
d = 0.065 m	L = 3.67 m	L = 8.06 m	L = 5.3 m
d = 0.08 m	L = 3.55 m	L = 8.03 m	L = 5.57 m

Table 4 Values of different head losses calculated for Ciumeghiu area

	DrenVSubIr (without filter)	DrenVSubIr (with filter)	Espadren
d = 0.05 m	h_v = 0.06	h_v = 0.06	h_v = 0.06
	h_o = 0.086	h_o = 0.418	h_o = 0.164
	h_r = 0.241	h_r = 0.476	h_r = 0.376
	h_i = 0.212	h_i = - 0.354	
d = 0.065 m	h_v = 0.06	h_v = 0.06	h_v = 0.06
	h_o = 0.089	h_o = 0.427	h_o = 0.185
	h_r = 0.225	h_r = 0.452	h_r = 0.355
	h_i = 0.225	h_i = - 0.339	
d = 0.08 m	h_v = 0.06	h_v = 0.06	h_v = 0.06
	h_o = 0.083	h_o = 0.424	h_o = 0.204
	h_r = 0.209	h_r = 0.438	h_r = 0.336
	h_i = 0.248	h_i = - 0.322	

DISCUSSION

Generally speaking, the values obtained in computing distances between drains by using Espadren were higher than the values obtained with DrenVSubIr, the differences being smaller (between 10 and 15%) in case of soils with high hydraulic conductivity and sizeable (between 40 and 50%) in the case of soils with low hydraulic conductivity.

Also, referring to the case of soils with low hydraulic conductivity (below 0,15 m/day) it can be observed that the maximum of distances between drains calculated with DrenVSubIr is obtained for 0,065 m drain pipe diameter while, the calculations realized with Espadren are indicated a growing trend of distances between drains, from 0,05 m drain pipe diameter to 0,08 m drain pipe diameter.

Sizeable differences were observed and in the case of horizontal head losses and in the case of radial head losses, especially for the soils with very low hydraulic conductivity.

The failure to take account of head loss at the water entrance in drains can lead to appreciable errors in drainage hydraulic design. In terms of filter material, the most important characteristic, with impact in designing distance between drains, is the thickness of the filtering material and not the initial permeability coefficient or permeability coefficient for filtering material after silting.

CONCLUSIONS

These two programs, DrenVSubIr and Espadren, which were used in this paper, are representing relative new programs in the frame of drainage design. They can offer the most proper information regarding the water table level and evolution, and as a consequence, they can offer tools for assessing drainage impact on environment. The industry of drainage programs knew in the last period a significant development, many researchers bringing their contribution in developing new platforms which are representing with high accuracy and fidelity the components and processes from surface drainage and drainage arrangements.

This paper presented only a small part from the capabilities of these programs, referring to the importance of head losses variation and distribution.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

THE CHARACTERISTICS OF BIOETHANOL FUEL IN INTERNAL COMBUSTION ENGINES WITH COMPRESSION-IGNITION

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SUMMARY

This present research concerns the use of alternative fuels as motor fuel. Indication arises from the European directives and constantly increasing energy need in the world. Laboratory tests have proved that retail farmstead ethanol fuels use high quality ethanol. Such production of biofuels is economically inefficient, especially for small-scale production. Considering that bioethanol used as motor fuel is not subject to the same requirements that apply to food industry, it can be produced by using less expensive production technologies. The general purpose is to expand the raw material base for production of bioethanol by reducing the cost price of farmstead ethanol. Farmstead ethanol differs from high quality ethanol in terms of the quantity of residue and water content. The article brings forth the differences between high quality ethanol and farmstead ethanol by using them as motor fuel in internal combustion engines working on the compression-ignition principle. Engine power and efficiency output parameters and the amount of components in the exhaust gas are observed. The impact of farmstead ethanol and high-quality ethanol on combustion process is analysed. The results of the analysis will henceforth be used in the process of working out a test methodology for using low-quality ethanol fuels in regular diesel engines.

Key words: *farmstead ethanol, distilled water, fusel oil, test methodology, engine parameters*

INTRODUCTION

It is mainly the high-quality spirit used in motor petrol containing ethanol, which makes the cost of fuel high. In support of this claim, laboratory tests were performed to examine the properties and composition of motor petrol E85. E85 contains 85% ethanol and 15%

petrol and was produced in the Republic of Latvia on the basis production licence LV 1000380004. The required content of unleaded petrol is between 14 and 22 per cent by volume (*European Standard CWA* 15293, 2009). Tests were performed pursuant to the test protocol of fuels control laboratory Analiit AA, analytical report SB 090701 2009 which showed 99.6% purity of ethanol contained in the fuel. Table 1 presents the fuels parameters used in the studies by Olt, *et al*. (2009) and Ritslaid, *et al*. (2010) and the European and United States of America requirements for ethanol used in fuels. One of the parameters is water content in bioethanol E85 fuel of Statoil petrol station which was 0.265% vol with no methanol content.

Table 1 Comparison of requirements for ethanol used for preparing bioethanol E85 and biopetrol (Ritslaid, *et al*. 2010)

Property	Units	Limits E85*	Test method	Bioethanol E85 of Statoil petrol station**	Denaturated ethanol ASTM D 4806
Higher alcohols (C3-C8)	V/V %	max 2.0	EN1601/EN 13132	0	
Ethanol content	V/V%				92.1
Ethanol+higher alcohols	V/V%	min 75		85,1	
Methanol	V/V %	max 1.0	EN1601/EN 13132	0	max 0.5
Ethers (5 or more atoms)	V/V %	max 5,2	EN1601/EN 13132	2.49	
Premium grade unleaded petrol specified by EN228:2008	V/V %	14-22	Calculated	14.64	
Water content	V/V %	max 0.3	ASTM E 1064	0.265	1.0
Inorganic chloride content	mg/l	max 1.0	ISO/6227/ ASTMD 512	0.192	max 32 mg/l

*Limits prefered SVENSK STANDARD SS 155480:2006 and European Standard CWA 15293:2005.
**analyzed Analiit-AA OÜ

There are strong indications that high-purity ethanol has been used for producing fuel, which increases the cost of the fuel. This is a waste of resources as fuel ethanol used as a motor fuel does not need to have the purity of drinking alcohol. By standards, bioethanol may contain up to 5.2 % vol. of ethers, 2 % vol. of higher (C_3-C_8) alcohols, at the same time, ethanol content in bioethanol fuel E85 can be minimum 75%. It is also important to know that higher alcohols increase the energetic value of bioethanol. The cost price of farmstead ethanol produced by a simpler production method is lower and the physical and chemical properties of the substance differ from the requirements set out in the standards.

The aim of the present article is to find out how ethanol fuels obtained by different production methods affect the output parameters of a compression-ignition test engine. Production of bioethanol with pilot scale equipment under laboratory conditions is a costly and time-consuming process. A solution is a consideration of possibilities for using quality ethanol diluted with distilled water in developing a motor test method to imitate farmstead ethanol that is obtained by a simpler and cheaper production method. The use of ethanol obtained from large-scale production and diluted with distilled water in the development of research method provides considerable savings. The task was to assess the difference of the effect of the residues of ethanol and farmstead ethanol on the combustion process of a test engine. The notion residue comprises also fusel oil which may have energetic value. As a result of the study, a comparative analysis, based on test data, a summary and description of further activities in assessing ethanol fuels using motor method conditions have been presented.

MATERIALS AND METHODS

In order to compare differences in engine output parameters, a fuel mixture prepared on the basis of standard ethanol diesel fuel was used as a test fuel. In order to obtain clear differences in test results, low-quality fuels were used (with high water content). One of the ethanol fuels was 97% ethanol diluted with water down to 60% and the other fuel was farmstead ethanol (58.9% vol.). Both ethanol fuels were prepared in the fuel laboratory of the Estonian University of Life Sciences. Farmstead ethanol was prepared from lignocellulosic material by means of a small-scale production device (Revenoor). A comparative analysis was performed on the properties of tested ethanol fuels, which includes the results of residue analysis and is displayed in figures in Table 2.

Table 2 The chemical and physical characteristics of ethanol and farmstead ethanol

Property	Testing method	Ethanol 60%	Farmstead ethanol 58,9%
Density, g/cm^3 20 °C	DIN EN ISO 12185	0,908	0,917
Recrement, g/l	ASTM D381-04	0.008	0.050
Colour	-	Colourless	Yellow
Flash point, °C	DIN EN ISO 2719	24,5	24,5
Vapor pressure, kPa 37.5 °C	ASTM D5191-07	14,5	14,5

Perennial grass, dried and stored in the previous summer, was used as lignocellulosic material. Biochemical tests for assessing lignin, cellulose and hemicellulose content of the material were carried out in the laboratory of the Estonian University of Life Sciences, the results are presented in Table 3.

Table 3 Test results of lignocellulosic material used for producing farmstead ethanol

Sample	Dry ingredient%	Lignin%	Cellulose%	Hemicellulose%
Perennial grass	94.78	4.96	32.92	25.53

In the laboratory for testing engines of the Estonian University of Life Sciences motor tests were performed with the compression-ignition engine D-120 and test stand Dynas3 LI-250. The choice of the test engine was based on its construction. This engine is air-cooled and enables to use an additional supply system and indicated pressure measuring devices. Indicated pressure was measured with the device *AVL Indimodul 621*. Pressure was measured with a *Kistler 701A*-type sensor which was installed in the opening of the pre-spark plugs of the engine. The results of the measurements were saved in the computer. The indicated pressure measuring device enables to perform measurements quickly and precisely and collect data to be processed in the computer. On the basis of the results comparative graphs were created and changes in the combustion process upon use of different fuels were examined. Additional supply system was used to supply the engine with different ethanol fuels. Basic supply system was used to ignite the fuel mixture with ordinary fuel (diesel fuel) as the ignition properties of ethanol fuel mixtures are worse. The additional supply device was a carburettor that was connected between the inlet manifold and the air measurement system. By adjusting the capacity of the main nozzle of the carburettor, optimal ethanol fuel delivery amount, at which the work of engine was still stable, was determined. Carburettor regulation characteristics for choosing ethanol fuel delivery amount were determined earlier (Olt, *et al.*, 2011) and are not discussed in detail here.

Motor tests on load characteristics modes were performed $n_{e,t1}$ = 1300 min^{-1} and $n_{e,t2}$ = 1800 min^{-1}. Fuel consumption B_f, air consumption B_a, exhaust gas temperature t_{egt}, temperature of motor oil t_o and composition of exhaust gas were measured. The choice of measurement points of the motor test was partly based on the exhaust gas measurement standard ISO 8178 (ISO, 2006). As the amount of farmstead ethanol was limited, a partial measurement cycle was carried out. At the maximum load mode of the engine, some instability was observed. The measurements were carried out at load modes T1 and T2 $T_{e,t1}$ = 112 N·m and $T_{e,t2}$ = 92 N·m, respectively.

Measurements of fuel consumption were performed for diesel fuel consumed at a separate pilot injection and for the ethanol fuel consumption in the engine with additional supply system. The measurement results were registered with electronic scales. Fuel consumption per hour B_{fet} *and* B_{fdk} was calculated on the basis of the measured test results. Also special consumption b_s, was calculated and a comparative analysis was performed.

Measuring device *Bosch BEA 350* was used for measuring exhaust gas composition. Exhaust gases were analysed for carbon dioxide (CO_2), carbon oxide (CO), hydrocarbon (HC), nitrogen oxides (NO_x) and oxygen (O_2). In addition, the device enabled to measure the temperature of motor oil, crankshaft rotational speed and excess-air ratio (λ). On the basis of measurement results, a comparative analysis was performed on the quantities of dangerous substances contained in exhaust gases by fuel.

RESULTS AND DISCUSSION

Capacity and economy-related parameters

Measurements were performed with all three fuels at similar load and speed modes. It appeared that with crankshaft rotational speed $n_{e,1}$ = 1300 min^{-1}, consumption of ethanol fuel mixture per hour B_{fet} was higher by 8.34% than that of farmstead ethanol fuel mixture (Figure 1). Consequently, with ethanol fuel mixture specific fuel consumption b_e was higher by 4.87% compared to farmstead ethanol. No significant differences in economy-related parameters of ethanol fuels (fuel consumption) were observed upon performing measurements at crankshaft rotational speed $n_{e,2}$ = 1800 min^{-1} (Figure 2). Differences were observed while comparing ethanol fuel mixtures and diesel fuel at higher load modes. At crankshaft rotational speed $n_{e,1}$ = 1300 min^{-1} special consumption of ethanol fuel mixture was higher by 37.6% compared to diesel fuel, special consumption of farmstead ethanol fuel mixture was higher by 34.5%. At crankshaft rotational speed $n_{e,2}$ = 1800 min^{-1}, special consumption of ethanol and farmstead ethanol fuel mixture were comparatively similar.

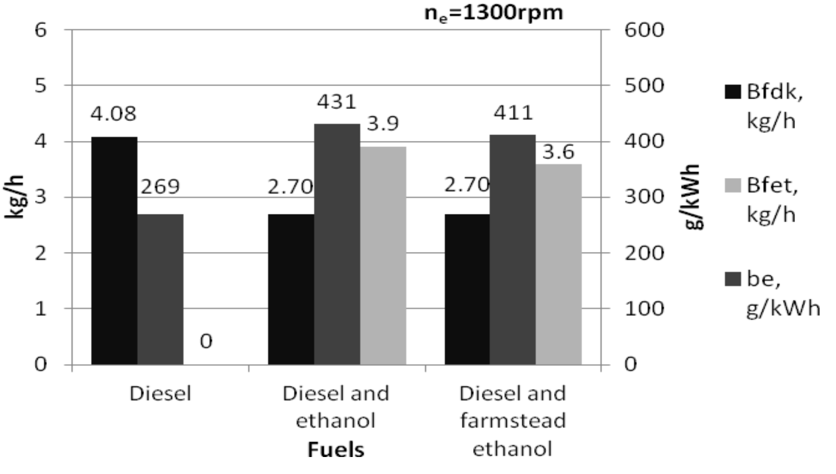

Figure 1 Test T1 comparison of fuel consumption and specific fuel consumption with tested fuels

Compared to the use of diesel fuel, ethanol fuel mixtures had 60% higher special consumption (Figure 2), which is due to a considerably lower calorific value Q_a of ethanol. Study of capacity and economy-related parameters of engine showed that the residues contained in farmstead ethanol have energetic value and the effect may vary depending on their amount. In the framework of the present study which showed a minimal share of residues in farmstead ethanol, the effect on the capacity and economy-related output parameters of the engine was not high compared to the use of ethanol. Ethanol diluted with water can be used for studying the use of ethanol fuels with a considerably small amount of residues in different engines in order to assess the capacity and economy-related parameters of engine.

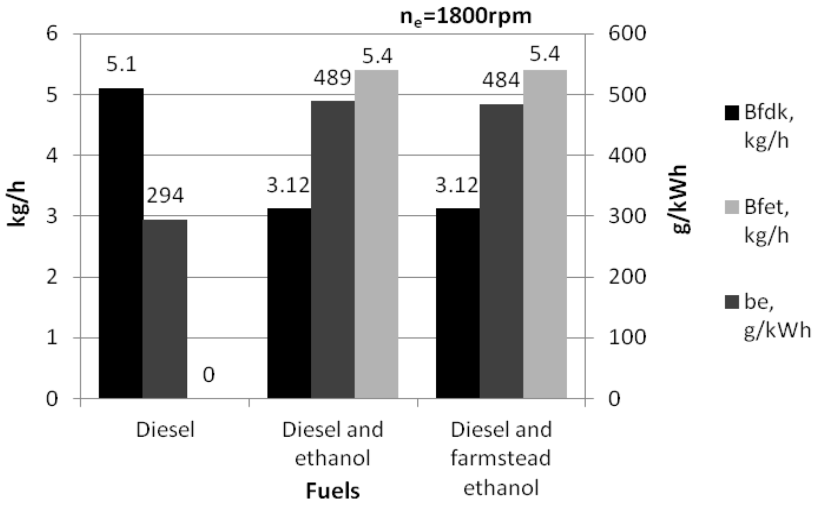

Figure 2 Test T2 comparison of fuel consumption and specific fuel consumption with tested fuels

Description of combustion process

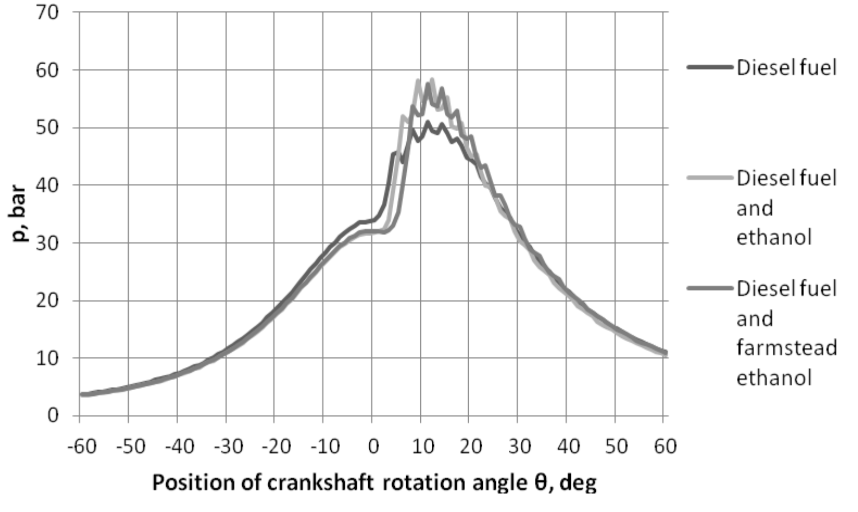

Figure 3 Test T1 comparative diagram of indicated pressure

Figures 3 and 4 display graphs with engine indicated pressure values with respect to crankshaft movement angle. Fifty measurement cycles in each measurement point and calculated mean values have been taken as basis for drawing the graphs. The results obtained in test T1 do not show significant differences between the use of ethanol and farmstead ethanol; the same cannot be said about test T2. In case of test T2, with the use of ethanol fuel, the maximum value of indicated pressure in combustion process is lower by 5 bars than with the use of farmstead ethanol (Figure 4), which also explains an increase in special consumption of fuel b_e in case of ethanol fuel mixture compared to farmstead ethanol.

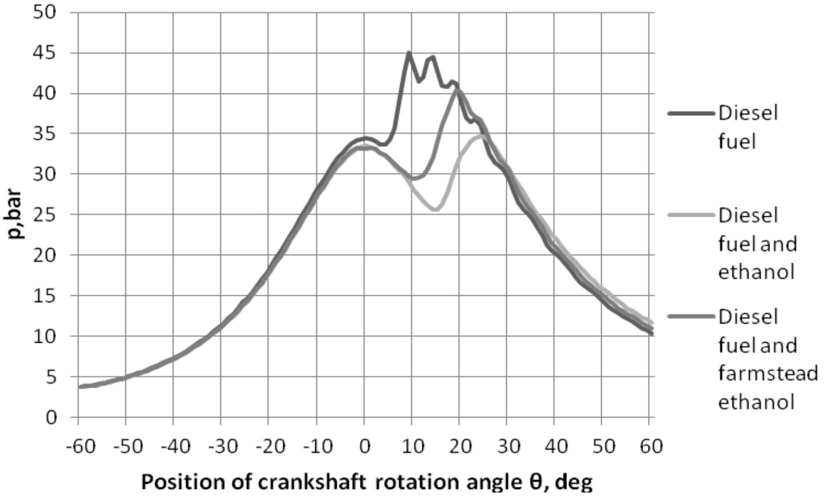

Figure 4 Test T2 comparative diagram of indicated pressure

Analysis of exhaust gases

Comparision of the results of the analyses of exhaust gases shows no significant differences in the use of ethanol and farmstead ethanol (Figure 5). Exhaust gases were tested for CH, NOx, CO and CO_2.. Differences in the amount of CH ja NO_x were observed in the use of diesel and ethanol fuels (Figure 6), which is subject to the temperature of combustion process.

According to the measurement results, the temperature of exhaust gases in outlet manifold was higher by 90º C with test T1 and 60º C with test T2 when diesel fuel was used compared to the use of ethanol fuels. As the temperature of exhaust gases increased, the share of hydrocarbons decreased and that of nitrous oxides increased significantly, which is functionally related to an increase in the combustion temperature (Pulkrabek, 1997). According to T1 test results, NO_x has decreased by 27% with ethanol fuels and 40% with farmstead ethanol fuel as compared to the use of diesel fuel. In test T2 NO_x values have decreased by 52% with ethanol and 51% with farmstead ethanol. The share of HC in exhaust gases has increased as compared to diesel fuel, which is related to incomplete combustion, especially with test T2 (Figure 4; 6). The results of analyses of the components of exhaust gases of fuels containing ethanol are quite similar, which is due to minor differences in the level of residues (Table 2).

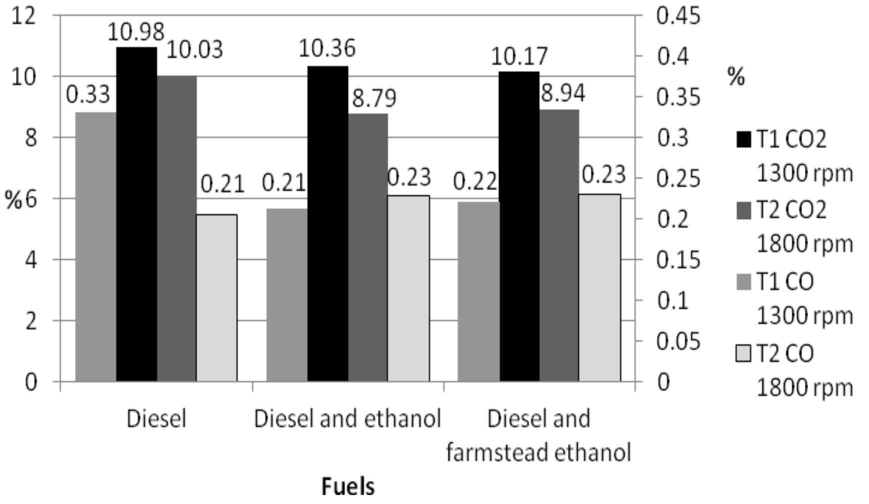

Figure 5 Comparision of the amounts of CO and CO_2 contaoined in exhaust gases with tests T1 and T2

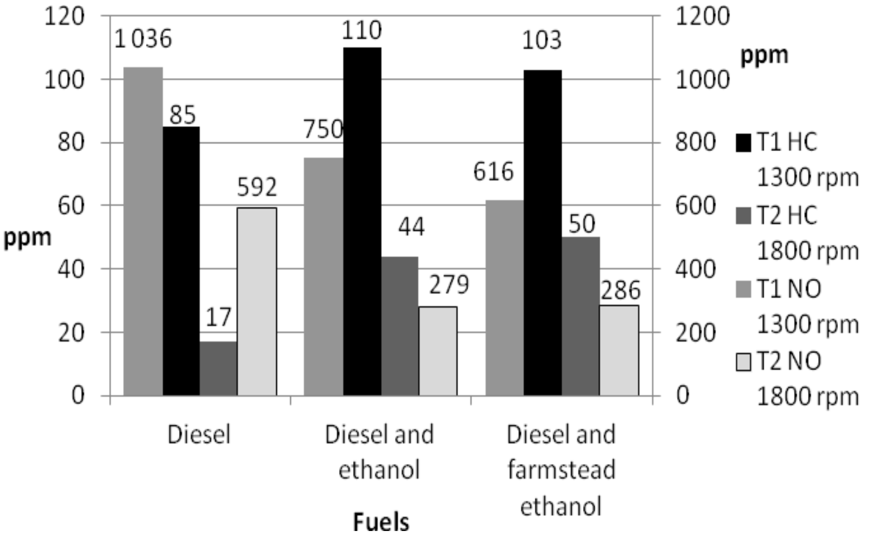

Figure 6 Comparision of the amounts of HC and NOx contaoined in exhaust gases with tests T1 and T2

CONCLUSION

The aim of the present study was to examine the effect of fuel with a lower absolute ethanol content on the output parameters of engine that depended on residue (fusel oil) content in the fuel. The results of the test indicate that it is possible to use ethanol diluted with distilled water as motor fuel. As farmstead ethanol produced by us was produced by the classical method and the residue content was considerably low (0.05 g/l), there is no significant difference in the measured parameters. According to the obtained results, pilot tests for assessing the economy and capacity-related parameters of engine can be performed by using ethanol diluted with distilled water imitating farmstead ethanol. At the same time, determining and assessing the volume of exhaust gases requires the use of farmstead ethanol that needs to be used in the engine because of the differences revealed in the test results. Further studies on exhaust gases require supplementary studies on the use of farmstead ethanol as the impact of residues on exhaust gases and the environment is not known.

Our primary interest is to study the peculiarities of the use of alternative fuel produced from lignocellulosic material (farmstead ethanol) as motor fuel and, first of all, a fuel to be used in regular engines. One of the stages of the classical production method used in production of bioethanol is distillation where water remains in ethanol depending on the speed of the process. Therefore, pilot tests will be performed with a compression-ignition test engine using diluted fuels with different ethanol contents (60%; 70%; 80% vol/vol).

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 66.094.3.097.8:662.756.3
Stručni rad
Expert paper

ANTIOKSIDANTI V BIODIZLU

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POVZETEK

Biodizel je za shranjevanje relativno nestabilen in hitro oksidira. Proces oksidacije biodizla se lahko upočasni z dodajanjem antioksidantov. Prispevek prikazuje vpliv različnih sintetičnih antioksidantov na oksidativno stabilnost biodizla, z uporabo določene preskusne metode.

Raziskan je bil biodizel, proizveden iz oljne ogrščice in soje glede na pet sintetičnih antioksidantov: Baynox plus, BHT, BHA, Baynox in Vitablend bioprotect 350.

Najbolj je proces oksidacije upočasnil Vitablend bioprotect 350 in sicer za približno 20 ur, medtem, ko so ostali štirje antioksidanti upočasnili proces oksidacije za približno 8 do 10 ur.

Oksidativna stabilnost biodizla je pomemben faktor, saj so metilni estri maščobnih kislin bolj občutljivi na oksidacijski razkroj kot mineralna goriva. Zato je v zadnji evropski specifikaciji za biodizel določena minimalna vrednost 6 h za indukcijsko obdobje pri 110 °C, merjeno z instrumentom Rancimat. Za zagotovitev te vrednosti je potrebna uporaba dodatnih antioksidantov.

Ključne besede: *obnovljivi viri energije, biodizel, antioksidanti, oksidativna stabilnost*

UVOD

Antioksidanti so snovi, ki se uporabljajo v izdelkih z maščobami in olji, da bi upočasnili ali preprečili procese oksidacije, ki jih spremljajo spremembe senzoričnih lastnosti barve in teksture. Po izvoru delimo antioksidante na naravne in sintetične.

Problem antioksidantov je zelo pomemben za področje bioogoriv v biodizlu (Berthiaume in Tremblay, 2006).

Sintetične antioksidante pridobivajo s kemijsko sintezo. So zelo učinkoviti, vendar je njihova glavna pomanjkljivost škodljivo vplivanje na zdravje, zato je njihova uporaba količinsko omejena in določena s predpisi.

Sintetični antioksidanti, ki se najpogosteje uporabljajo v biodizlu, so: BHT, TBHQ, Baynox plus, BHA …

Zanimanje za naravne antioksidante se je v zadnjih letih precej povečalo, saj je opravljenih že mnogo raziskav na to temo, ki kažejo, da lahko mešanice naravnih antioksidantov konkurirajo sintetičnim.

Preden se katerikoli antioksidant uveljavi na trgu, je zelo pomembno, da spojina ne kaže nikakršnih nezaželenih interakcij z gorivom, njegovimi dodatki ali motornim oljem. Za varno uporabo antioksidantov obstaja katalog testnih metod, ki določa, katere antioksidante lahko testiramo glede na možne neželene stranske učinke.

Biodizel, kot vsa naravna olja in maščobe zaradi atmosferskega kisika počasi oksidira. Na ta način proizvedene substance lahko povzročijo škodo npr. v motorju, na tesnilih. Zato je oksidativna stabilnost tako pomembna kriterijska lastnost biodizla. Z Rancimatom se hitro in učinkovito določi. Rancimat se lahko uporabi tudi za določanje učinkovitosti antioksidantov.

Cilj prispevka je ugotoviti, kateri od petih antioksidantov (Baynox plus, BHT, BHA, Baynox in Vitablend bioprotect 350) najbolj podaljša oksidativno stabilnost biodizla, proizvedenega iz 80 % semena oljne ogrščice in 20 % semena soje.

Slika 1 Oljna ogrščica

Biodizel je varen za uporabo v vseh konvencionalnih dizelskih motorjih, saj ponuja primerljive vozne lastnosti in podobno življenjsko dobo motorja kot običajna petrokemična dizelska goriva. Poleg tega se bistveno zmanjšajo emisije škodljivih snovi v ozračje. Glede na vsebnost žvepla, aromatskih spojin, vžigne točke in biološke razgradljivosti je biodizelsko gorivo z ekološkega vidika veliko bolj sprejemljivo za uporabo kot običajno petrokemično dizelsko gorivo.

Goriva, narejena iz rastlinskih olj, dolgo niso bila sprejemljiva, ker so bila veliko dražja od naftnih goriv. Zaradi konstantnega višanja cen surove nafte in z naraščajočo negotovostjo, povezano z njeno dostopnostjo, se je v zadnjem času ponovno povečal interes za uporabo rastlinskih olj v dizelskih motorjih. Rastlinsko olje je moč pridobivati iz več kot 350 različnih vrst rastlin, vendar je med temi vrstami le peščica takih, pri katerih je predelava v biodizelsko gorivo ekonomsko sprejemljiva (uporablja se samo tiste rastlinske vrste, iz katerih se lahko iztisne največ olja). Med ta olja sodijo sončnično, kokosovo, palmovo, sojino, bombaževčevo, repično, arašidovo, koruzno, oljčno olje itd. (Demirbas, 2003).

'Bio' predstavlja obnovljiv in biološki vir energije, medtem ko se 'dizel' nanaša na njegovo uporabo v dizelskih motorjih v obliki tekočega goriva. Biodizel je za razliko od naftnega goriva manj vnetljiv in ni eksploziven.

Onesnaževanje zraka s toplogrednimi plini je že vrsto let resen problem, s katerim se ukvarjajo številni strokovnjaki iz različnih področij. Seveda za ta problem ni kriva samo industrija, ki proizvaja ogromne količine toplogrednih plinov, pač pa v zadnjih desetletjih predvsem avtomobili s svojimi motorji.

METODE

Natančni vzorci antioksidantov se odtehtajo s analitsko tehtnico.

Rancimat je moderni instrument, ki se upravlja s pomočjo osebnega računalnika (slika 2). Z njegovo pomočjo se prepričljivo določa oksidativno stabilnost biodizla in biodizelskih mešanic, ki so določene z normativi. Programska oprema Rancimata omogoča avtomatsko ovrednotenje podatkov in evaluacijo rezultatov, kot tudi bazo podatkov s preprostim upravljanjem z ogromno količino podatkov.

Slika 3 Rancimat (Westbrook, 2005)

REZULTATI Z RAZPRAVO

Westbrook, 2005Vitablend bioprotect 350 dosega najboljše rezultate med vsemi danimi vzorci, saj indukcijsko fazo najbolj zakasni v vseh treh koncentracijah. Drugi najboljši rezultat je dosegel Baynox plus, in sicer za največ 10,21 ure pri koncentraciji 200 ppm. BHT, BHA, in Baynox so indukcijsko fazo zakasnili za manj kot 9 ur pri najvišji dodani koncentraciji.

Kot je razvidno iz preglednice 1, Vitablend bioprotect 350 dosega najboljše rezultate med vsemi danimi vzorci, saj indukcijsko fazo najbolj zakasni v vseh treh koncentracijah. Drugi najboljši rezultat je dosegel Baynox plus, in sicer za največ 10,21 ure pri koncentraciji 200 ppm. BHT, BHA, in Baynox so indukcijsko fazo zakasnili za manj kot 9 ur pri najvišji dodani koncentraciji.

Preglednica 1 Indukcijski čas (h)

Antioksidanti/koncentracija (ppm)	0	100	150	200
B+	5,33	8,53	9,63	10,21
BHT	5,33	7,73	8,19	8,36
BHA	5,33	7,41	8,13	8,38
Baynox	5,33	8,14	7,58	8,46
Vitablend bioprotect 350	5,33	13,96	15,81	19,75

Oksidativno stabilnost biodizla pri koncentraciji 100 ppm najbolj poveča Vitablend bioprotect 350 za 13,96 ure, sledi mu Baynox plus za 8,53 ure, Baynox za 8,14 ure, BHT za 7,73 ure in BHA za 7,41 ure.

Pri dodani koncentraciji 150 ppm indukcijsko fazo najbolj zakasni Vitablend bioprotect 350 za 15,81 ure, Baynox plus za 9,63 ure, BHT za 8,19 ure, BHA za 8,13 ure in Baynox za 7,58 ure.

Ob najvišji dodani koncentraciji 200 ppm ponovno najbolj vpliva na oksidativno stabilnost biodizla Vitablend bioprotect 350, ki je dosegel zakasnitev za 19,75 ure, nato mu sledijo Baynox plus z 10,21 ure, Baynox z 8,46 ure, BHA z 8,38 ure, ter BHT z 8,36 ure.

SKLEPI

Izboljšanje oksidativne stabilnosti biodizla se izvaja z namernim dodajanjem antioksidantov ali s spremembo profila maščobnih estrov. Spreminjanje koncentracij antioksidantov je pokazalo, da je učinkovitost antioksidantov odvisna od njihove koncentracije in vrst biodizla.

Primerjali smo različno oksidativno stabilnost biodizla pet različnih antioksidantov v laboratoriju. To področje je zelo aktualno in zanimivo.

Za določanje oksidativne stabilnosti biodizla je na razpolago več metod, ki so vse bolj ali manj enako učinkovite. Tudi antioksidantov, ki dajejo zahtevane učinke, je veliko.

Ena od večjih tehničnih težav, s katerimi se sooča biodizel, je občutljivost na oksidacijo po izpostavljanju kisika v zraku, ki se pojavi zaradi vsebnosti nenasičenih verig maščobnih kislin.

Oksidacija maščobnih kislinskih verig je kompleksen proces, ki poteka z različnimi mehanizmi. Poleg prisotnosti zraka, vplivajo na proces oksidacije biodizla tudi razni drugi dejavniki, vključno s prisotnostjo svetlobe, povišane temperature, tujih materialov kot so kovine, peroksidi in antioksidanti, kot tudi velikost površine med biodizlom in zrakom.

Biodizel je lahko proizveden iz različnih mešanic oljne ogrščice, soje, sončnic, rabljenega jedilnega olja, odpadnih živalskih maščob. Vsako olje ima drugačne karakteristike ob dodajanju različnih antioksidantov, zato je potrebno raziskati, kateri je najučinkovitejši in najprimernejši.

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ANTIOXIDANTS IN BIODIESEL

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SUMMARY

The biodiesel is relatively unstable for storing and oxidizes quickly. The oxidation process of the biodiesel can be slows down by adding antioxidants. This paper presents the effect of various synthetic antioxidants on the biodiesel oxidation stability by using specific test method.

Biodiesel was produced from rapeseed oil and soybean oil. It was tested regarding to five synthetic antioxidants: Baynox plus, BHT, BHA, Baynox and Vitablend bioprotect 350.

Vitablend bioprotect 350 produced the greatest delay in the induction period, about 20 hours while the other four compounds produced a delay for around 8 to 10 hours.

Oxidation stability of biodiesel is an important issue because fatty acid methyl esters are more sensitive to oxidative degradation than mineral fuel. Therefore, in the latest European specification for biodiesel a minimum value of 6 h is specified for the induction period at 110 °C as measured by the Rancimat instrument. In order to reach that value the use of additional antioxidants is required.

Key words: *renewable energy sources, biodiesel, antioxidants, oxidation stability*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 662.756.3:665.75
Prethodno priopćenje
Preliminary communication

THE INFLUENCE OF ENGINE LOADS ON SMOKE EMISSIONS OF BIODIESEL BLENDS

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SUMMARY

The purpose of this study was to identify from experimental researches the results regarding the smoke emissions of a four stroke, four cylinder, direct injection medium power diesel engine at partial loads operating on diesel fuel (DF), rapeseed methyl ester (RME), degummed and filtered (5 μm) pure rapeseed oil (RO100) and its blends with diesel fuel: 20 % pure rapeseed oil-80 % diesel fuel (RO20), 50 % pure rapeseed oil-50 % diesel fuel (RO50), 75 % pure rapeseed oil-25 % diesel fuel (RO75) compared to diesel fuel.

The main properties of tested fuels (density, kinematic viscosity, oxidation stability, acid value, peroxide number, coke content, water content and cetane number) has been determined.

The tractor diesel engine subjected to experiment has four cylinders, 51.5 kW and 4760 cc. The engine was loaded at wide open accelerator position, and run at different speeds between 1200 and 1950 rpm and different engine loads: 90%, 85%, 80%, 75%, 70% and 65%. The speed and engine load were recorded from digital indicator of the test ring. The load on the dynamometer was measured by using a strain gauge load sensor. The rotation sensor was used to measure the speed of the engine.

The high values of smoke emissions for tested fuels can be found for diesel fuel on the engine load of 75% at 1400 rpm (2.61 m^{-1}). The most important increase of smoke emissions for pure rapeseed oil is on the engine load 70% at 1300 rpm (1.86 m^{-1}). For the blend RO20 the maximum value of smoke emissions is on the engine load 75% at 1400 rpm (2.42 m^{-1}). RME has the maximum value for smoke emissions on the engine load 90% at 1700 rpm (1.94 m^{-1}).

Key words: *rapeseed oil, diesel engine, fuel blends, cetane number, viscosity, smokes emissions*

INTRODUCTION

Biodiesels are fuels that are made from renewable oils that can be usually used in diesel engines without major modification. These fuels have properties similar to fossil diesel oils and have reduced emissions from a cleaner burn due to their higher oxygen content.

In order to insure the protection against future petroleum shocks, the countries that are members of the European Union, and also the Energy Department of the United States of America have elaborated a series of strategies based on the orientation of the petroleum's imports towards "the regions of the calmer world" and also on the development of alternative energies. Within the programs launched in numerous countries, the substitution fuels are based on oxygenated organic compounds, such as: alcohols, ethers, organic esters and their derivates.

The growing concerns on the long-term availability of diesel and its environmental disadvantage have necessitated the search for a renewable alternative to diesel fuel. Biofuel can provide a feasible solution to these problems; known liquid biofuels are fuels derived from alcohol and vegetable oils (Bhupendra *et al.* 2010).

The strong development of the SVO (straight vegetable oils) sector worldwide calls for these new dynamics to be channeled from the outset, by drawing up precise and compulsory specifications adapted to the supply chain from plantation to end user, with transparency and traceability: a quality norm or standard (Sibidé *et al. 2010)*. A standard from Europe of German origin, exists today for SVO fuel use: DIN 51605. These recommendations mostly apply to rapeseed oil (Remmele and Thuneke 2007).

Some of the physical-chemical properties of the fuels, influence the processes that take place in diesel engines, such as the density, viscosity, superficial tension, the temperature of self combustion, while others influence the engine's wear (alkalinity, mineral and organic acidity, the content of sulphur, water, color,etc.).

Viscosity influences the engine's feeding and the fuel's spraying in the combustion chamber. The increase of viscosity disfavors the spraying and combustion of the fuel in the engine. A too viscous fuel will worsen the formation of the fuel mixture, because the drops, being big and penetrating, will reach the opposite wall of the injector. The contact surface is colder, which will determine a break in the chain of the combustion reactions. Because of this, white smoke will appear, having a sharp smell (due to the products of an incomplete combustion: aldehydes and acids). On the other hand, for the fuels with small viscosity, that favors a fine spraying, the mass of drops being smaller, the jet's penetration in the dense air is not sufficient. Black smoke is formed, typical for the lack of oxygen (the combustion is realized with excess of fuel) (Burnete *et al.* 2008).

Transesterification of the vegetable oils is used to decrease the viscosity of the vegetable oil; however, other properties of the oil remain same and this new fuel was called as biodiesel (Leon *et al.* 2004). This biodiesel contains no petroleum, even though it can be used in pure form in the compression ignition engine with little or no engine modification, or it can be used in blend with petroleum diesel at any level (Pugazhvadivu *et al.* 2009).

The purpose of this work is to investigate the effect of biofuels based on rapeseed oil on the diesel engine smoke emissions compared with diesel fuel.

MATERIAL AND METHODS

In this study, the D-2402 type compression ignition engine type was fuelled with 6 different fuels blends: 100 % diesel fuel (DF); 100% rapeseed metyl ester (RME); 80% diesel fuel - 20% crude rapeseed oil (RO20); 50% diesel fuel - 50% crude rapeseed oil (RO50); 25% diesel fuel 75% crude rapeseed oil (RO75); 100% crude rapeseed oil (RO100).

The main properties of the blends have been determined and are presented in Table 1.

Table 1 The main properties of the tested fuels

Property parameters	DF	RME	RO20	RO50	RO75	RO100	Test methods
Density, g/cm^3	0.834	0.883	0.855	0.880	0.897	0.915	SR EN ISO 3675
Kinematic viscosity (40 ^{o}C), mm^2/s	2.346	4.466	4.424	9.654	17.859	34.358	ASTM D445
Oxidation stability, h	>58	6.84	>58	9.5	7.79	5.92	ISO 6886
Acid value, mg KOH/g	0.04	0.292	0.625	1.358	1.904	2.008	DIN 51558
Peroxide number, mmol O_2/kg	0	3.13	2.13	5.20	6.33	13.59	ISO 3960
Coke content, max wt%	0.009	0.022	0.078	0.183	0.259	0.4	ASTM D524-76
Water content, mg/kg	37	77	138	297	405	535	ISO 12937
Cetane number	57.6	50.3	56	53.8	49.3	48.1	ASTM D613

The experimental stand equipped with a diesel engine D-2402 type, hydraulic brake and data acquisition system, allows measurement of engine speed, braking force, fuel consumption, testing duration coolant engine temperature, oil temperature and ambient parameters.

The main features of the engine subjected to experiment are shown in Table 2.

Table 2 The main technical characteristics of the engine used in experimental tests

Engine type	D-2402
Number of cylinders	4
Bore, mm	110
Stroke, mm	130
Engine capacity, cm^3	4760
Compression ratio	17:1
Injection pressure, daN/cm^2	175±5
Injection timing advance, ca	24°
Effective power, kW	51.5
Nominal speed, rpm	1800
BSFC – Brake Specific Fuels Consumption, g/kWh	244

The experimental stand (Fig.1) equipped with a tractor diesel engine D-2402 type, hydraulic brake, exhaust analyzer, sensors that measure the instantaneous values of the some parameters and data acquisition system, allows measurement of engine speed, braking force, fuel consumption, testing duration coolant engine temperature, oil temperature and ambient parameters.

For measurements the smoke emissions in case of diesel engine supply with blends have been used an exhaust analyzer BEA 350 DTM type made by Bosch with RTM 430 type smoke-opacity tester module. BEA 350 is a modular system for measurement the pollutants emitted by diesel and Otto engines. It is used for certification of emission engines.

The experiments have started firstly with diesel fuel and when the engine reached the operating temperature, it was loaded with a hydraulic dynamometer.

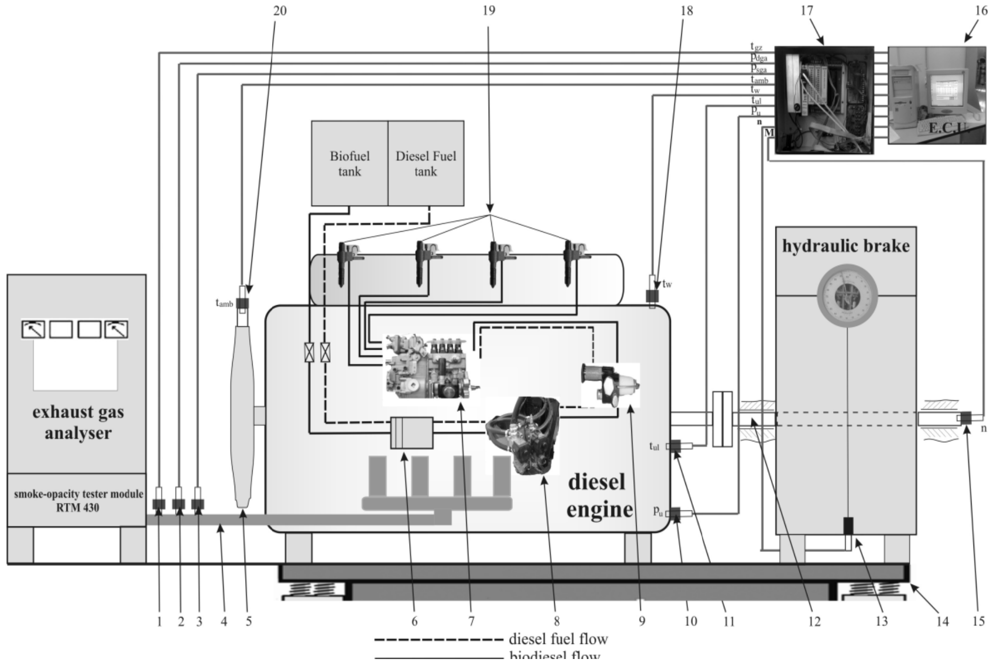

Fig 1 Experimental stand and sensor positioning scheme
1 - exhaust gas temperature sensor; 2- exhaust gas dynamic pressure sensor 3- exhaust static pressure sensor ; 4 – exhaust pipe; 5- engine radiator; 6- switch distributor; 7- in-line pump injection; 8- biofuel heating element; 9- pump supply; 10- oil pressure sensor; 11- oil temperature sensor; 12- hydraulic brake shaft; 13 – engine torque sensor; 14 - shock absorbers 15- rotation sensor; 16 - electronic computing unit; 17- electronic block (multiplexer module); 18- water temperature sensor; 19- injectors; 20- ambient temperature sensor;

The engine was loaded at wide open accelerator throttle, and run at different speeds between 1200 and 1950 rpm and different engine loads: 65%, 70%, 75%, 80%, 85% and 90%.

RESULTS AND DISCUSSION

Smoke formation occurs primarily in the fuel-rich zone of the cylinder, at high temperature and pressure. If the applied fuel is partially oxygenated, locally over-rich regions can be reduced and primary smoke formation can be limited (Puhan *et al.* 2005).

Genesis of smoke emission is correlated in some areas with incomplete burning in combustion chamber due to the very short fuel-air mixture formation.

Figure 2 represents the variation of smoke emissions of fuel based on rapeseed oil compared to diesel at different partial loads 65%, 70%, 75%, 80%, 85%, 90% and engine speeds between 1200 rpm and 1950 rpm.

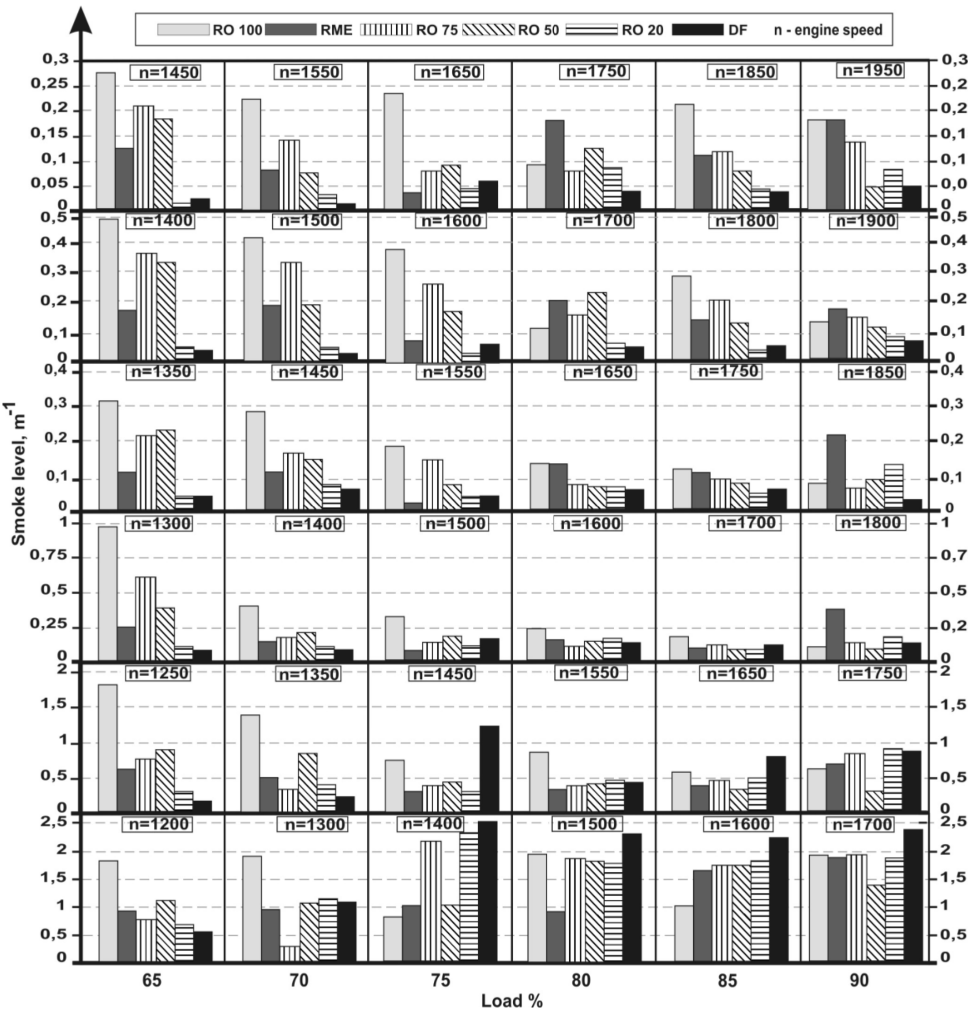

Fig. 2 Smoke emissions as a function of load at various engine speed

Figure 2 shows that at constant engine loads, as speeds increase, the smoke emissions for all fuels has a tendency to decrease, due to the thermal engine regime when fuel combustion of fuels tend to be more complete .

The reduction in smoke level at higher load may be due to better combustion at higher load and more biodiesel is required.

Table 3 The evolution of smoke emissions of biofuels based on fuels rapeseed oil compared with diesel fuel

Load, (%)	Fuels	Smoke emissions evolution
90	RO100	- 12,46 %
	RME	- 1,13 %
	RO75	- 6,23 %
	RO50	- 39,94 %
	RO20	- 5,38 %
85	RO100	- 26,74 %
	RME	- 23,10 %
	RO75	- 18,54 %
	RO50	- 24,92 %
	RO20	- 21,88 %
80	RO100	+ 10,74 %
	RME	- 37,78 %
	RO75	- 10,09 %
	RO50	- 7,81 %
	RO20	- 13,68 %
75	RO100	- 44,66 %
	RME	- 67,55 %
	RO75	- 28 %
	RO50	- 56,88 %
	RO20	- 35,11 %
70	RO100	+ 91 %
	RME	+ 36,98 %
	RO75	+ 89 %
	RO50	+ 72 %
	RO20	+ 23,28 %
65	RO100	+ 99,76%
	RME	+ 98,78 %
	RO75	+ 97,97 %
	RO50	+ 99,87 %
	RO20	+ 23,95 %

Higher smoke emissions for all experienced fuels is observed in the case of the load between 65% and 90% at speeds n = 1200, 1300, 1400, 1500, 1600 and 1700 rpm. This is explained because of the low thermal engine regime

Maximum value of smoke emissions is for diesel fuel (DF) when smoke level is 2,51 m^{-1} at 75% engine load and the speed of 1400 rpm .

RO20 has value of smoke emission very close to those of diesel fuel due to high percentage of diesel fuel in blend.

Table 3 summarizes the evolution of smoke emissions of fuels based on rapeseed oil compared to diesel fuel depending on the engine load.

At the engine loads of 90%, 85%, 80% and 75%, the value of smoke emissions of fuels based on rapeseed oil are lower in most case than smoke level of diesel fuels.

For RO100, smoke emissions level has lower values with 12.46%, 26.74% and 44.66% for 90%, 85% respectively 75% engine loads. A slight increase (10.74%) is observed at engine load of 80%.

In the case of RME decreasing of smoke emissions compared to smoke level of diesel fuel is between 1.13%, 23.10%, 37.78% and 44.66% at 90%, 85%, 80% respectively 75 % engine loads.

For blends RO20, RO50 and RO75, smoke emission values recorded maximum reduction of 56.88% for RO50 at 75% engine load and minimum 5.38% for RO20 at 90% engine load.

The fuels based on rapeseed oil has greater smoke emissions level than value of smoke in case of diesel fuel for 60% and 65% engine loads. This may be due to heavier molecular structure, double bonds in vegetable oil chemical structure and higher viscosity of rapeseed oil and their blends. These factors are responsible for higher smoke emissions resulting in incomplete and sluggish combustion at this engine loads.

CONCLUSIONS

Based on the results of this study, the following specific conclusions were draw:

- the physiochemical properties of fuels based on rapeseed oil are comparable to those of diesel fuel;
- it was found that smoke emissions are much better values for blend RO50 than for diesel fuel emission values, reaching up to 56.88 % more lower at 75% engine load;
- at the same regime load, RME emits smoke emissions up to 67.55 % lower than diesel;
- smoke level using biofuels at a lower engine load, has a increase tendency than at higher engine load due to the lower thermal engine regime and higher viscosity of rapeseed oil and their blends.

The experimental test showed that biofuel based on rapeseed oil is viable in terms of environmental pollution for its use as fuel.

ACKNOWLEDGEMENTS

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 331.101:621.8:631.372
Stručni rad
Expert paper

RESEARCHES REGARDING THE NOISE CONVERSION FROM TRACTOR ENGINE IN ORDER TO REDUCE THE INTAKE MANIFOLD NOISE

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SUMMARY

With the increasing of the internal combustion engines and mechanical equipments, chemical and noise pollution effects is more present in environment. Researchers developed technologies and systems to meet pollution requirements. On the other hand traditional internal combustion engines with a functioning efficiency between 25% - 45% develops a significant amount of residual energy such as thermal energy, vibration energy and acoustic energy.

The paper presents the research carried out in order to develop an equipment based on Helmholtz resonator for reduce de intake manifold noise and convert it into electric current. The device detailed in the paper provided a side branch resonator and electromagnetic transducer for collect the sound pressure level in the resonance chamber and convert it into low power electric signal.

***Key words**: pollution, energy conversion, noise, noise reduction*

INTRODUCTION

By increasing the number of internal combustion engines used by the vehicles and mechanical equipment, chemical and noise pollution laws are more and more severe. Researchers develop technologies and systems to meet the pollution reduction requirements. The conventional internal combustion engines with efficiencies between 25% - 45% in running conditions [1] developed a significant amount of residual energy such as heat, vibration energy and acoustic energy. [5].

Noise conversion was less investigated in the literature due to energy density lower than other sources (Table 1) [9].

Table 1 Comparisons of the power densities for different energy sources [9]

Source of energy	Acoustic noise	Ambient light	Vibrations (piezoelectric)
Power density and performance	0,003 $\mu W/cm^3$ at 75 dB 0,96 $\mu W/cm^3$ at 100 dB	100 mW/cm^2 (direct sunlight) 100 $\mu W/cm^2$ (lighting in office)	200 $\mu W/cm^3$

Considering the noise as a waste acoustic energy spread in environmental and it environmental effect, an equipment able to collect the intake air noise and convert it into electric signal was develop.

THE SOURCE OF THE ENGINE INTAKE MANIFOLD NOISE

Pressure oscillations in intake manifold depend by the engine rotation speed, the number of cylinder having a frequency calculated with the relation:

$$f = \frac{n \cdot i}{60 \cdot \tau}, \tag{1}$$

where n is rotation speed of engine operating in rev/min, i the number of engine cylinder, τ depends on the constructive characteristics of the engine (τ=1 for two-stroke engine and τ=2 for 4-stroke engine). In the equation 1, the i number of the cylinder corresponds to the number of the cylinder communicated with the same intake manifold.

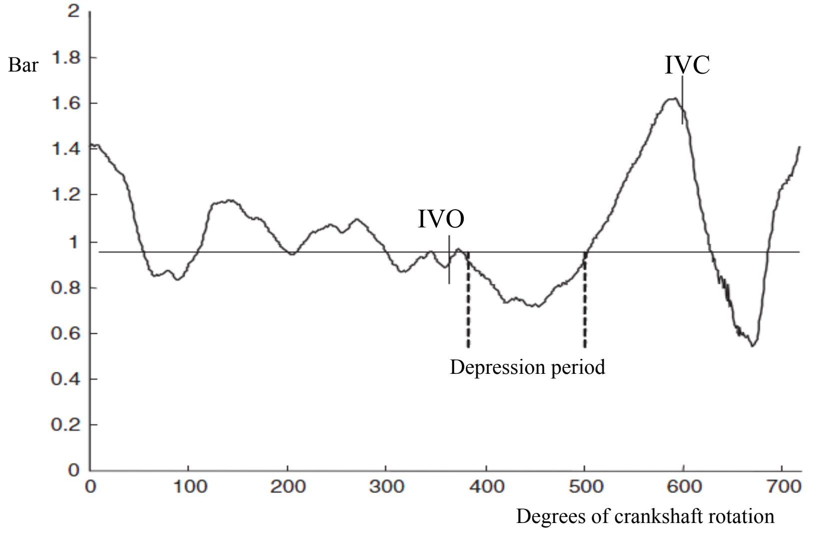

Figure 1 Intake port pressure trace, ¾ rated speed, full load (Dunkley, 1999) [6]

An example of pressure variation is presented in figure 1 for a single cylinder internal combustion engine [6]. The peak pressure corresponds to the time of Intake Valve Closing (IVC) and has a value of 0.6 bar, thus obtaining a noise level of 190 dB for a considered reference pressure of 20 μPa. From here it can be concluded that the intake system of automotive is a major source of waste noise and this energy have a possible potential for converting acoustical energy into electrical energy.

It also show that for an gape of 270° of crankshaft rotation pressure variation approaches a sinusoid with an amplitude peak over 0.4 bar Energy conversion is of interest because this period reveals a significant variation of pressure. This period can be exploited by converting the acoustic signals into electrical signal inducing a predictable periodicity accompanied by a differential pressure falling into electromagnetic transducer sensitivity.

THE PROPOSED EQUIPMENT DESCRIPTION

The principle of noise reduction in intake is based on techniques for reducing acoustic noise using Helmholtz resonator. What is customizes for the proposed system is that an electromagnetic transducer is attached to the resonance chamber, for convert sound pressure into electrical signals. The characteristic of this resonator is the fact that the back side wall of the resonance chamber is in fact an aperture to the electromagnetic transducer. That has an influence through the volume of the resonator, which is changing in accordance with the intake pressure oscillation.

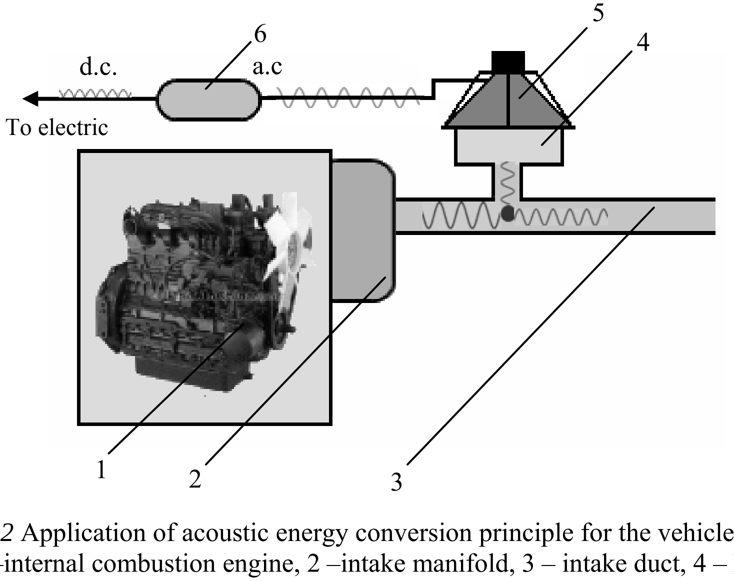

Figure 2 Application of acoustic energy conversion principle for the vehicle intake system: 1 –internal combustion engine, 2 –intake manifold, 3 – intake duct, 4 – Helmholtz resonator, 5 – electromagnetic transducer, 6 –rectifier bridge (converts AC to DC)

The system is shown in Figure 2 and consists of: the engine 1 which is the source of generated noise, intake manifold 2, air duct 3, Helmholtz resonator 4, electromagnetic transducer 5 and rectifier bridge 6.

Variation of sound pressure in the inlet system (fig. 2) can be represented by vibri - mechanical attached simplified scheme (fig. 3). This system corresponds to a pressure oscillating circuit equivalent, in terms of similarities between the electric and the acoustic effect (fig. 4). Resonator acoustic impedance Z_s is in parallel with downstream pipe impedance Z_d, and Z_u is upstream pipe impedance.

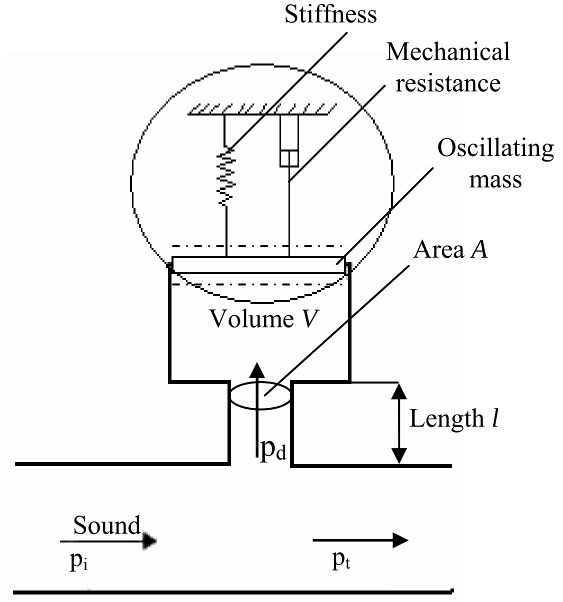

Figure 3 Simplified acoustic system and the transducer presented as a mechanical oscillator

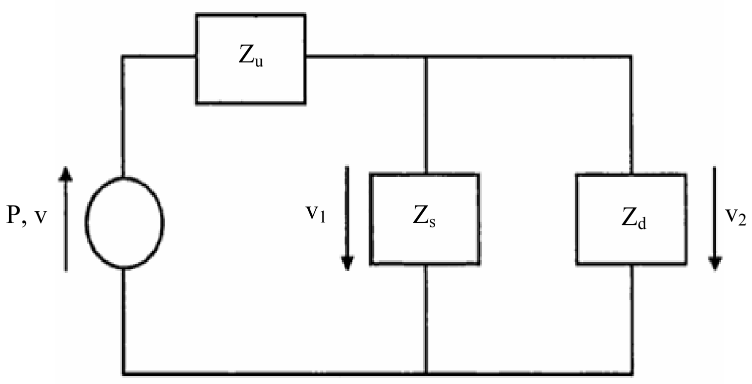

Figure 4 Equivalent acoustic circuit

Acoustical circuit from Figure 4 respect the acoustical analogies of Kirchhoff's law in which the volumetric acoustical speed is analogous to the current and the pressure analogous to voltage. Thus we can write the relations [2]:

$$p = v_2 Z_d + (v_1 + v_2) Z_u \quad (2)$$

$$v = v_1 + v_2 \quad (3)$$

$$v_1 Z_s = v_2 Z_d \quad (4)$$

Acoustic impedance Z_s is composed of the capacity X_C (depending on the resonator volume), the inductance X_L (depends on the length and the section of the pipe) and the resistance R_A (depending on the pipe length, pipe sectional area and internal perimeter of the pipe).

Helmholtz resonator can be built in such a way as to show a certain resonant frequency depending on the following parameters: the speed of sound *c*, the pipe sectional area *A*, the connecting tube length *l* and resonant volume *V*. Resonant frequency of the resonator can be calculate depending by the sound speed *c* using the relation [7]:

$$f_0 = \frac{c}{2\pi} \sqrt{A / l \cdot V} \quad (5)$$

Should be take into consideration the membrane oscillation because this effect has an influence on the resonant chamber volume value.

ELECTROMAGNETIC TRANSDUCER

Electromagnetic transducer is coupled resonator further (fig. 3). It converts acoustical energy using Faraday's law: the coil oscillation through electromagnetic field generates a voltage *U* [8]:

$$U = B \cdot l \cdot u \quad (6)$$

B – The magnetic field [T]

l – The length of wire in the coil [m]

u – The speed of that coil is moving through the magnetic field [m/s]

The transducer mobile part acts as a mechanical oscillator (Figure 3). It has an oscillating mass *m* (diaphragm and coil mass), a mechanical resistance R_m (damping), and also a stiffness *s*. The pressure variation on the membrane surface acts the oscillator after a law of motion described by equation (7) [4]:

$$m\frac{d^2x}{dt^2} + R_m\frac{dx}{dt} + s \cdot x = \frac{p}{S} \tag{7}$$

where *p* is the pressure variation at the membrane, *S* the membrane surface, *x* membrane displacement and *t* is the time.

Also, if the transducer is connected at a consumer (eg a lamp) into equation (7) must take into account the Lorentz force that opposing the motion and witch is defined by relationship:

$$F = B \cdot I \cdot l \tag{8}$$

where *I* is the current generated by coil.

To use the supplied alternating current by the electromagnetic transducer, it should be turned into DC bridge rectifier using a double alternation scheme.

It was taking into consideration the fact that the proposed system would be more effective if it is attached to an exhaust system [7]. Significant pressure variation from exhaust system allows a more efficient conversion of powers at least double compared to the inlet. However the recorded high temperatures at exhaust represent a risk factor by electromagnetic transducer life time point of view. In this case we recommend the use of high thermal properties transducers able to respond at the same time to the principles of converting noise into electric current.

CONCLUSIONS

Used of the described device for air intake system of the internal combustion engines has the following advantages:

- Acoustic energy recovery and conversion to electricity;
- Noise reduction caused by the pressure variation collected into Helmholtz resonant chamber (additional volume of air);
- The possibility of using this device to monitor the load of the air filter;
- Electromechanical transducer must be designed to cover a large frequency range from the intake noise at all engine operating speeds and loads;
- Conversion of sound pressure waves from intake pipes is possible because there is a plane wave propagation, higher energy value compared to spherical waves propagated in the environment;

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 662.76:631.3
Originalni znanstveni rad
Original scientific paper

USE OF NATURAL GAS IN AGRICULTURAL MACHINERY

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SUMMARY

Since the creation of internal combustion engines in industrialized countries, there is a constant desire for replacement of liquid petroleum origin fuels with alternative fuels. Unfortunately, mankind has managed to find ideal fuel for internal combustion engines. Practical application and examination of several alternative fuels it appears that in the near future only worth replacement is contributed to natural gas. Some estimates indicate that in the world today there are about ten million vehicles driven by CNG, with their tendency to spread their number in the field of agricultural machninery. This paper provide some structural proporties and performance of current systems for engine power with natural gas, also in this article was described concrete implementation of this alternative system on a tractor engine. In this article was performed simulation of tractor performance in case when tractor engine was powered with primary and alternative fuel. Siumlation was performed in market-leading ISO approved, 1D engine and gas dynamics simulation software package from Ricardo Software.

***Key words**: CNG, agricultural machinery, IC engine, simulation*

INTRODUCTION

The idea of using natural gas as a fuel for internal combustion engine is not novel. Way back in 1915 was the first application of natural gas in transport vehicles, and from very beginning of IC engines in industrialized countries there is a idea for replacement of petroleum origin fuel with some alternative fuel. This is particulary evident in recent several decades, which is associated with a sharp increase in the number of the motor vehicles, the emergence of the oil crisis, the tightening of legal regulations concerning the content of components in toxic combustion products and an increase in oil prices. Today, the extensive research are conducted with the main aim of finding available, cheap and ecologically clean fuel for internal combustion engines [1]. It can be say that mankind is not yet managed to find an ideal fuel for internal combustion engines, but with practical implementation and testing of several alternatives fuels, it appears that natural gas is immediately applicable and the best solution in a close future. This fuel is the cleanest and cheapest fuel, and is very safe during operation with this fuel also planet earth has a relatively sufficient amounts. Many countries of the world have enacted national programs for the conversion of its transport vehicles with conventional fuels with natural gas.

European Economic Commission in 2001. adopted a resolution which predicts that to 2020. the translated vehicles on natural gas will be of about 10% of Europe transport vehicles, which would make a population of 23 million motor vehicles and require the exploitation of about 47 billion cubic meters of natural gas annually [2,3].

National Program of Japan predicts that in 2011. in Japan will be around one million motor vehicles on the natural gas. Statistics from the first half of 2011. say that the world's leaders are Argentina (1,703,156 - every second vehicle) and Brazil (1,532,844), and Europe Italy (432 900)[3,4]. According to the National Association of Russian gas in 2007. the number of vehicles using natural gas in the world was 6.364 million (out of 780 million), with their tendency of continuous growth.

It is estimated that until 2020. the world will have about 40-45 million vehicles powered on natural gas. Application of natural gas as fuel motor vehicles in Serbia and countries in the region are in the very beginning.

NATURAL GAS

Natural gas as a fuel for internal combustion engine is a combustible mixture of hydrocarbon and smaller amount of other gases. It is located below the earth`s surface (the fossil origin) with oil as a gas cap or independently in the form of gas fields. There are two opinions about origin of oil and natural gas (organic and inorganic). Today organic theory is prevailing, according to which the millions of years ago there was a deposition of debris plants and animals on the bottom of the sea and ocean. These remnants of the animals and plants was covered with the layer of mud, sit and sand through many years. In these conditions was developed high temperatures and pressures, which led to the decomposition of plant and animals residues in anaerobic conditions without the presence of oxygen, At depths of 1 to 6 km ant temperatures 60-150 ^{o}C oil was formed, and on the higher pressures and temperatures was formed natural gas. In the case that oil and nautural gas are found together (in the form gas cap), than the gas unusally has a greater amount of heavy hydrocarbons. The composition of natural gas varies from the place of its finding, and his typical composition is presented with table 1 [5].

After extracting the raw natural gas from sites, with special procedures are removed all impurities such as water and other hydrocarbon gases, oil resudials and mechanical impurities in order to bring its quality in prescribed limits. In its purest form this gas is supplid to the consumer almost as pure methane, and natural gas proporties practical are determinated by proporties of methane.

Table 1. Natural gas composition

Methane CH_4	97%
Ethane C_2H_6	0.92%
Propane C_3H_8	0.36%
Butane C_4H_{10}	0.16%
Oxygen O_2	0-0.08%
Nitrogen N_2	0.94%
Carbon dioxide CO_2	0.527%
Rare gases (Ar, He, Ne, Xe, H_2S)	trace gases

EXPLOITATION PARTICULARS OF CONVERTED VEHICLE ON NATURAL GAS

As in the case of any technical system, and in converted the interplay of natural gas vehicles can cause the deterioration of security and reduction of resources of the vehicle due to improper exploitation. It is known that every technical product is a potential hazard in the case of not respected rules of its exploitation, and converted natural gas vehicles can not exempt from this. That is why the users of such vehicles often have several questions: How to exploit the agricultural vehicles? Which should be followed and what should be avoided! Considered the structural difference between the generation unit for natural gas and the option of a different composition, the basis of proper operation would be: "For each vehicle should be a special manual operation, the driver should be comply with the rules contained in it. " Within this paper you will see one general principle of exploitation, which could be characterized by all vehicles and equipment for all ages natural gas. To ensure proper technical operation of vehicles converted to natural gas are essential to continuous technical control and maintenance of the technical working condition of all elements of the device for natural gas, and timely measures to eliminate perceived failure. During the exploitation process should follow some basic rules:

- the vehicle is fitted only with additional components and subsystems homologated devices natural gas;
- installation of additional equipment for natural gas in the vehicle must to be exported only to trained and verified in person;
- filling up with natural gas shall be verified on the compressor cells by professional and trained personnel;
- despite vehicle can use gasoline and natural gas as fuel, simultaneously bringing the two types of fuel are not permitted;
- special attention should be paid to the tightness of all connections and subsystem devices natural gas;
- in the case of detection of the appearance of unwanted emphasis on natural gas, it is necessary to close outlet valve on the tank (to prevent bringing gas into the engine);

- not allowed exploitation of vehicles with tanks expired exploitation or expired control testing;
- at the termination of the engine ignition system should be excluded in case non-use vehicles over an extended period of time to close the output valve on the tank, and from the system to release a residual gas;
- control of the vehicle wiring can be run only in terms of absence of gas the part of the system for natural gas, which is located in the engine compartment;
- in case of fire it is necessary to turn off the ignition, close the outlet valve tank and fire fighting access (sand, clothing, cold water);

During vehicle operation are categorically prohibited from:

- work with natural gas engine with an invalid device for natural gas;
- carrying out any repairs or replacement of elements of the device for natural gas, if there is gas in the system;
- performing tightness devices through an open flame;
- heat engine (in winter) through an open flame;
- carrying out repairs technological welding procedures;
- application of fuse strength greater than 5A in electrical installation equipment for natural gas.

In the process of exploitation of vehicles converted to natural gas appear to some inevitableoperations such as starting the engine, translating from one engine to another type fuel, stopping the engine, the performance of different regulatory actions on some

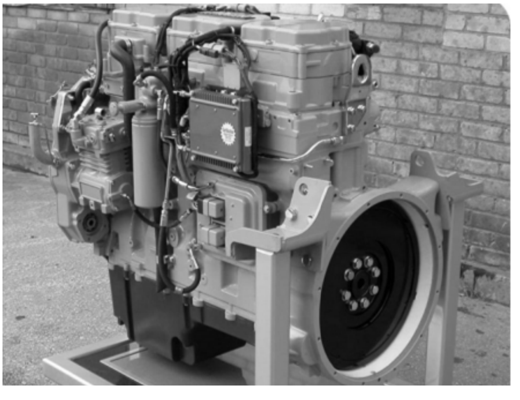

Figure 1. Diesel engine powered on CNG

One of the most promises way for using CNG in agricultural machinery is Dual-Fuel system - fig. 1. Dual-Fuel technology enables a heavy-duty diesel engine to operate on a high proportion of natural gas. Firstly, a Dual-Fuel engine is a diesel engine, unchanged in its basic thermodynamic operation. However, with Dual-Fuel, diesel combustion is used only to ignite a metered charge of natural gas and air. A small injection of diesel is made to ignite the gas and air. This is called a pilot injection. The pilot injection is delivered by the standard, un-modified diesel injection system fitted to the engine. Once ignited, the gas and air charge burns rapidly and cleanly. By using diesel pilot ignition and retaining the diesel's high compression ratio, the gas combustion can be achieved at very lean air-fuel mixture ratios. Known as "lean-burn", this delivers high efficiency and low NOx emissions [6].

The high compression ratio of the diesel engine can be retained due to the high auto-ignition temperature of methane, the main constituent of natural gas. A diesel engine is the most efficient engine for road-transport. It is significantly more efficient than a spark-ignited engine due to [6]:

- Higher compression ratio (higher compression pressure in the cylinder)
- Very lean-burn combustion (excess air combustion)
- No throttle to cause additional pumping work on the engine

The Dual-Fue engine retains all of these attributes and achieves similar efficiency to the diesel engine – after all, it is still a diesel engine. Some results of testing tractor powered with CNG and with ordinary diesel was presented throgh table 2.

Table 2. The results of testing of tractor K-701 with electromechanical governor

Work quality		
Basic performance of the engine ЯМЗ-240 БМ2	diesel fuel regime	dual-fuel regime
Engine speed at peak power, rpm	1920	1900
Peak power, kW	197.3	202.8
Engine torque at peak power, Nm	982	1019
Fuel consumption, kg/h	49.3	15.0/33.0*
Brake specific fuel consumption, g/kWh	250	237
Engine speed at peak engine torque, rpm	1150	1500
Peak engine torque, Nm	1378	1276
Engine torque reserve, %	40	25
Productivity		
Technology operation	productivity ha/h, (costs rub/ha)	
	diesel regime	dual fuel regime
Cultivation (harrowing) of wheat stubble	8.4, (236.2)	8.2, (158.6)
Cultivation (harrowing) of pea stubble	7.5, (234.7)	7.3, (157.5)
Cultivation of wheat stubble by combined tools	4.6, (303.6)	4.4, (190.2)
Cultivation (harrowing) of sunflower stubble	6.0, (290.2)	6.0, (161.2)
Tillage of wheat stubble	2.15, (290.2)	2.10,(178.8)

ENGINE MODEL AND SIMULATION

Modeling an engine through software is one of the least expensive and quickest methods of obtaining reasonably accurate data based on reasonably accurate assumptions. Operating conditions and modifications that would require significant amounts of time and money to test can be modeled to obtain information that is accurate enough to make informed decisions and determine major effects. Information that could not be obtained through conventional methods can be obtained from a model as well.

The details of the flow as calculated in the flow network of both engine models are obtained as a solution of quasi-one dimensional compressible flow equations governing the conservation of mass, momentum and energy. The flow network of both conventional and unconventional piston movement is discretized into a series of small volumes and the governing equations are then written in a finite difference form for each of these elementary volumes. A staggered mesh system is used, with equations of mass and energy solved for each volume and the momentum equation solved for each boundary between volumes. The equations are written in an explicitly conservative form as:

$$\frac{dm}{dt} = \sum_{boundaries} m_{flux} \tag{1}$$

Equation (1): mass continuity equation.

$$\frac{d(m_{flux})}{dt} = \frac{dpA + \sum\limits_{boundaries}(m_{flux}u)}{dx} - \frac{4C_f \dfrac{\rho u^2 dxA}{2D} - C_p\left(\dfrac{1}{2}\rho u^2\right)A}{dx} \tag{2}$$

Equation (2): Conservation of momentum equation.

$$\frac{d(me_n)}{dt} = p\frac{dV}{dt} + \sum_{bound.} m_{flux}H - h_g A(T_{gas} - T_{wall}) \tag{3}$$

Equation (3): Conservation of energy equation.

If the engine cylinder element has one zone, the entire cylinder is treated as one region, while in the latter the cylinder is divided to two regions (unburned and burned) which share a common pressure. The two-zone model is used to capture the chemical processes taking place during the combustion period in more detail. Combustion models may be used with either single or two-zone engine cylinders, but for this research was used two zone models.For the single zone model we have the energy equation refer to (4) as below:

$$\Delta(mu) = \sum_{i=1}^{nvalves} m_i h_i - Q - P\Delta V \tag{4}$$

As far as the high-pressure part of the cycle is considered, the most important process is combustion. In program Ricardo Wave model of combustion can be selected between several options, from theoretical models with constant volume or constant pressure heat release, over Viebe-function based heat release models, to quasidimensional two-zone model of turbulent flame propagation [7]. Complete engine model in software Ricardo/WAVE is presented in fig 2.

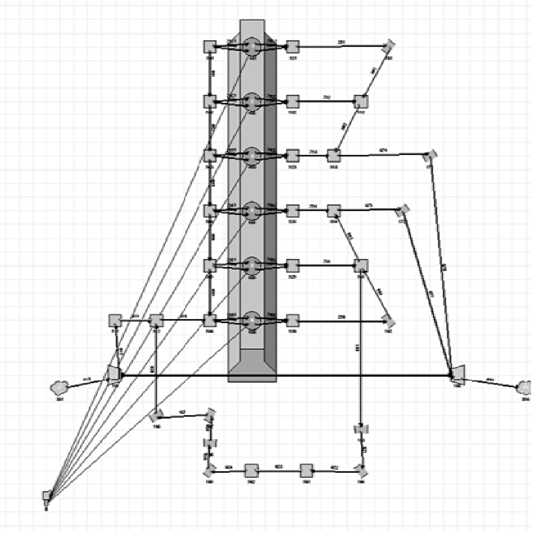

Figure 2. Diesel engine model in Ricardo/WAVE

RESULTS

Finally we can compare simulation results for the case when is engine powered with ordinary diesel fuel and with mixture of diesel-methane fuel. Defining input values of engine and fuel parameters are of significant importance for prediction of power and efficiency performance. Main engine data is defined with proper selection of several parameters one of them are: bore, stroke, number of cylinders and rod lenght, also it is very important to specify open valves duration and timing. Simulation of heat addition was performed with Diesel Wiebe model. Important parametar in this research was to find appropriate mixture of methane and diesel fule. For this article was examined case when engine was powered with diesel-methane mixturu in ratio of 70% diesel fuel and 30% of methane fuel. This also produces graphical output showing sample equilibrium mole fractions for all 11 species of the burned gas mixture as functions of equivalence ratio and temperature at a pressure of 1 bar. Similar plots are produced for mixture specific heat, enthalpy, and molecular weight, this values are presented with fig 3. and fig. 4.

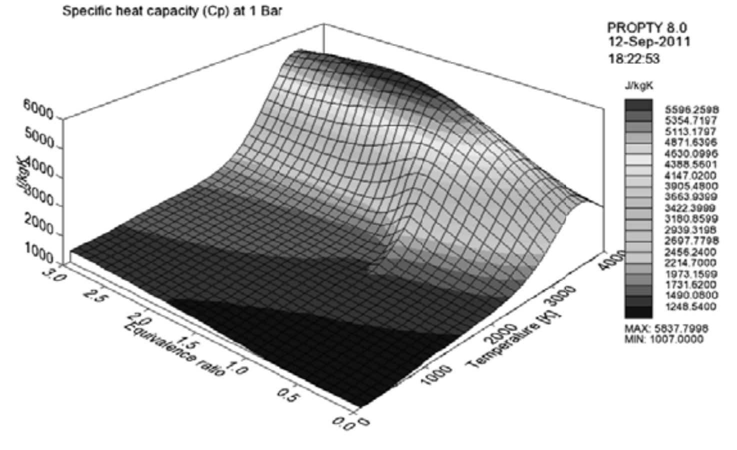

Figure 3. Specific heat capacity at 1 bar of diesel-methane mixture (30-70)

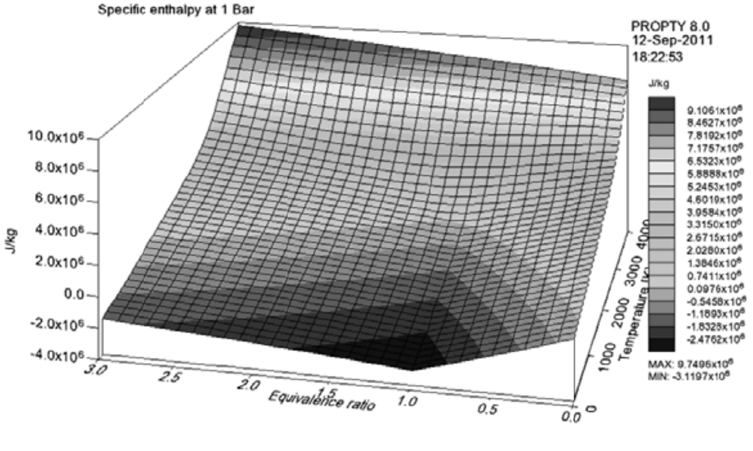

Figure 4. Specific enthalpy at 1 bar of diesel-methane mixture (30-70)

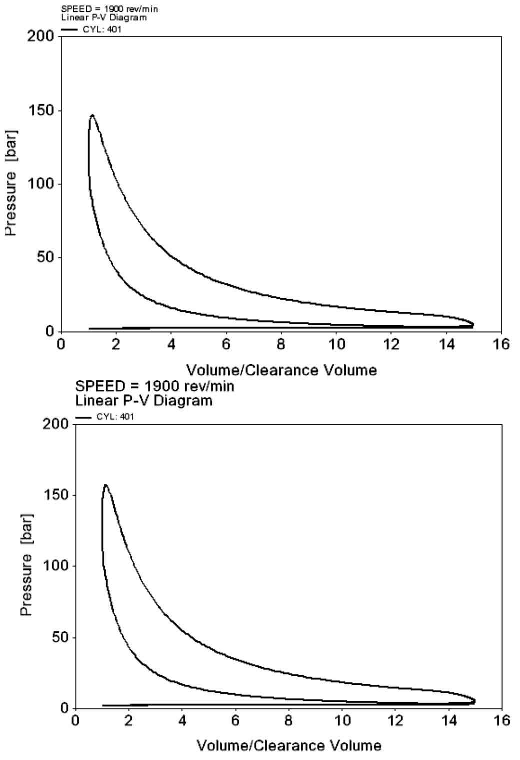

Figure 5. Comparison of PV diagram in relation to used fuel, diesel fuel (left) and diesel-methane mixture (right)

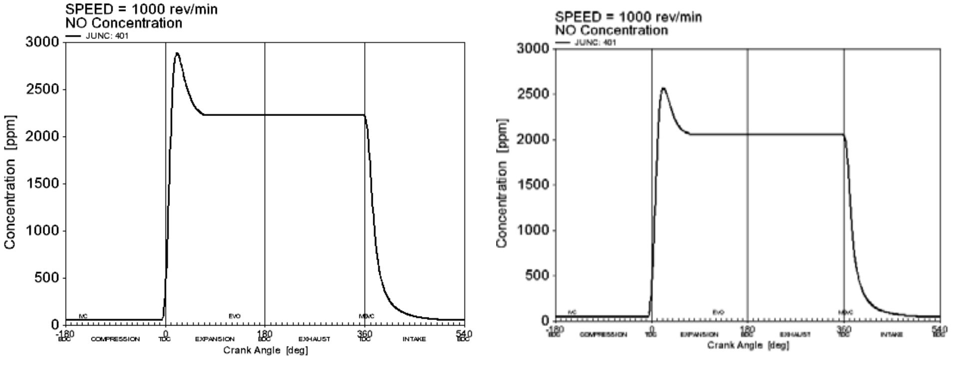

Figure 6. Comparison of NO concentration at 100 rpm in relation to used fuel, diesel fuel (left) and diesel-methane mixture (right)

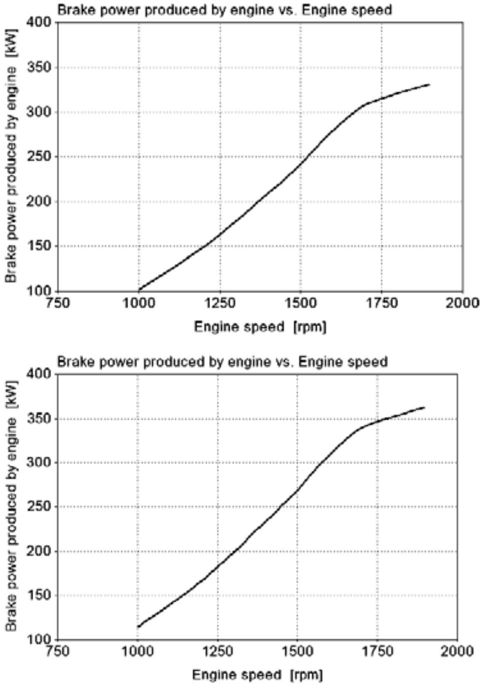

Figure 7. Comparison of engine power in relation to used fuel, diesel fuel (left) and diesel-methane mixture (right)

It can be concluded that in case when engine is powered with diesel-methane mixture there is an improvement in engine power, this can be seen from fig. 7. Also, there are a significant differences in PV diagrms in the case when the engine is powered with Diesel-CNG fuel results can be seen from digarms on fig. 5. Finally this approach can reduce pollution formation of NO_x such comparison is shown in fig. 6.

CONCLUSION

Today, it can be concluded that was finished epoch of cheap oil, natural gas with its resource, economic, environmentally and security benefits who are most helpful, cleanest and safest available fuel for internal combustion engines. It is the fuel that is good for the owner of the vehicle, for the engine and for the environment. The best solution for conversion of diesel engines that are already in exploitation is solution of dual-fuel version. Because of complex construction of natural gas tank, at this moment would be rational to perform the conversion to compressed natural gas (CNG), and in the following period try to make a solution with liquefied natural gas (LNG). According to the results presented in this paper it is clear that use of natural gas in agricultural mechanisation has fully justified, since it is possible with substantial economic effect to achieve productivity, meet all technical requirements and agro-technical measures as well as in the case of application of conventional liquid fuels. So, it is belived that the conversion of natural gas vehicles and mechanisation can find wide application in all fields, especially in agriculture. The main drive unit in agricultural mechanization is the diesel engine, converting this engine on the mono fuel version is unsuitable, because it requires a radical reconstruction of engine construction, so the only reasonable option is dual fuel system. The main advantages of this system are: less pollution, less noise, reduction of vibration, longer engine life and in some case can be expected more power.

ACKNOWLEDGMENTS

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.372:629.3.042.2
Prethodno priopćenje
Preliminary communication

ANALYSIS OF AIRFLOW DIRECTION ON HEAT LOSS FROM OPERATOR'S BODY IN AN AGRICULTURAL TRACTOR CAB

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SUMMARY

The stream of the airflow of the certain temperature from ventilation outlets is the only active method for cooling an operator's body in a common ventilated and air-conditioned tractor cab. Since there are many inter- and intra-individual differences regarding to human physiological and psychological response as well as clothing insulation, activity, air temperature and air movement preference, the ventilation system must be under the control of the operator. Heat loss from the body will be depending on the characteristics of the airflow over the surface of the body. This airflow will depend on design and setting of the air distribution system in the cab as well as its position related to operator's body.

The aim of the research is to analyse the influences of different airflow direction on operator's heat loss, under the same boundary conditions, mass flow rate and air temperature. For this purpose, the virtual thermal manikin was placed in the model of the tractor cab, and influences are assessed by comparison of dry heat losses from the manikin's segments. The analysis was done by computational fluid dynamics, using published experimental and other data for verification purposes. The results show that different layouts and setting of air distribution systems produce different segmental and total dry heat loss from the virtual manikin's body, under the same cab thermal conditions.

Key words*: tractor cab, ergonomic, microclimate, air distribution, CFD*

INTRODUCTION

An evaluation of thermal conditions in tractor cab can be done by using human subjects, by direct measurement of microclimate physical quantities on points distributed over the cab space or by using special human-shaped sensors 1, 5, 7, 10, 12. The complex human-shaped measuring instruments, so called thermal manikins, are the most suitable for reliable and repetitive objective evaluation of thermal conditions in vehicle cab. When mathematical modelling of cab thermal processes is performed, usually based on computational fluid dynamics (CFD), this model is should be verified by some of experimental methods. In order to evaluate the results, some kind of human thermoregulation model should be implemented, in such a way that results correspond to local and overall thermal sensation of exposed person. In this paper, as an influencing factor on thermal sensation, distribution of conditioned air in relation of operator's body will be analysed.

From the fact that primary purpose of cab's AC system is to obtain thermally comfortable environment for the operator, it is reasonable to cool first the operator, not the entire cab. However, for operator's thermal sensation and thermal comfort, local microclimate parameters are very important, because, for example, powerful air-conditioner could produce unpleasant stream of air, e.g. draught. On the other hand, despite of sufficient cooling load of the AC system in some cases, some part of the operator's body could not be sufficiently cooled if they are not exposed to the airflow. Therefore, airflow characteristics must be suited to the individual human thermal sensation, e.g. personalized, meaning that ventilation must be under the control of the operator 6, 9.

METHOD

The assessment of airflow influence on thermal sensation is based on comparison of segmental and total equivalent temperature between different cases of airflow. The CFD results are validated using the experimental results available in the literature. In order to isolate the influence of isothermal airflow on the operator, all other parameters were kept constant and uniform.

Three different layouts of typical air distribution design used in tractor cabs are analyzed here: system with air outlets on instrument panel, system with nozzles on front part of the ceiling and system with nozzles on side part of the ceiling. Every system design was run under four different airflow directions in relation to the operator's body.

Equivalent temperature t_{eq} is defined as temperature of a homogenous space, with mean radiant temperature equal to air temperature and zero air velocity, in which a person exchange the same heat loss by convection and radiation as in the actual conditions 14. Equivalent temperature could be evaluated for whole body $t_{eq\,body}$ or for body segments $t_{eq\,segm}$. For the manikin with uniform and constant skin temperature (t_s = 34°C), as suggested in standard for thermal environment in vehicles 14, equivalent temperature is calculated as follows:

$$t_{eq} = t_s - \frac{Q}{h_{cal}}\text{, °C,} \tag{1}$$

where Q [W/m^2] is convective and radiative heat loss in actual conditions, and h_{cal} [W/m^{2}K] is combined heat transfer coefficient, determined during calibration in a standard environment. The calibration of the virtual manikin was made in the model of chamber according to conditions given in 7, with homogenous climatic conditions (t_a = 24°C, v_a = 0.05 m/s). The combined heat transfer coefficients for body segments are calculated according to:

$$h_{cal} = \frac{Q_{cal}}{t_s - t_a} = \frac{Q_{cal}}{34 - 24}\text{, W/m}^2\text{K} \qquad (2)$$

Virtual thermal manikin

The operator's body is modelled as a simplified humanoid in sitting position, where limbs and neck are presented as cylinders, trunk and head as elliptic cylinder, and elbows, shoulders and knees as spheres. Main body dimensions are adopted from CATIA database for 50th percentile European male, but slightly adapted to the simplified shape of the virtual operator's body. The body is divided in 18 segments. Fig. 1.

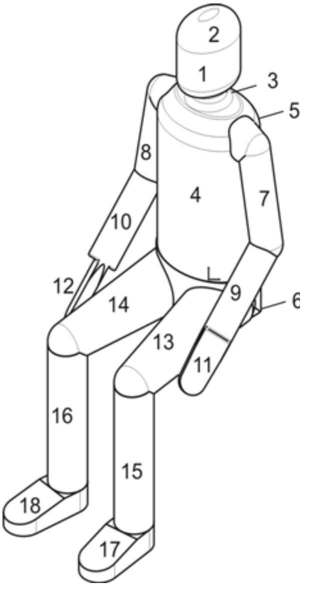

Fig. 1. Virtual manikin and its division in segments

Body surface has constant and uniform temperature of 34°C, with emissivity of 0.95 (common values for thermal manikin surface 2, 3, 8, 13, 14). The setting of type, size and characteristics of volume mesh and other software parameters (for example models of boundaries, turbulence model and number of iteration) were verified by the comparison with published experimental results for segmental and total heat transfer under the same conditions. The model of manikin showed good agreement with experiments on thermal manikins exposed to uniform horizontal airflow 8, as well as in natural convection 3, 13.

Parameters for comparison were segmental dry heat loss (boundary heat flux in W/m^2) and local air velocities. Verification of a model is inevitable step of every computational simulation of fluid flow and thermal processes.

Numerical model of computational domain

Numerical simulations were done in STAR CCM+ software, using CAD model of the left cab half, with extracted volume of the manikin. The entire cab interior presents single fluid region, meshed in the same way for all simulation cases. Volume mesh with approximately 67000 finite volume elements (for one half of the cab interior) was generated from the surface mesh with minimum surface size of 0.018 m on manikin surface, 0.036 m on the other walls and 0.009 m on the air duct surfaces. These mesh refinements were done on zones where larger gradients of the parameters could be occurred. The volume mesh is consisted of polyhedral core mesh and of near-wall prismatic cell layers. A prism layer mesh is composed of orthogonal prismatic cells next to the wall boundaries, in order to simulate turbulence and heat transfer more accurately. For the manikin surface six prism layers are used, with stretch factor of 1.5 and thickness of 0.030 m. Other wall surfaces have two prism layers with thickness of 0.060 m.

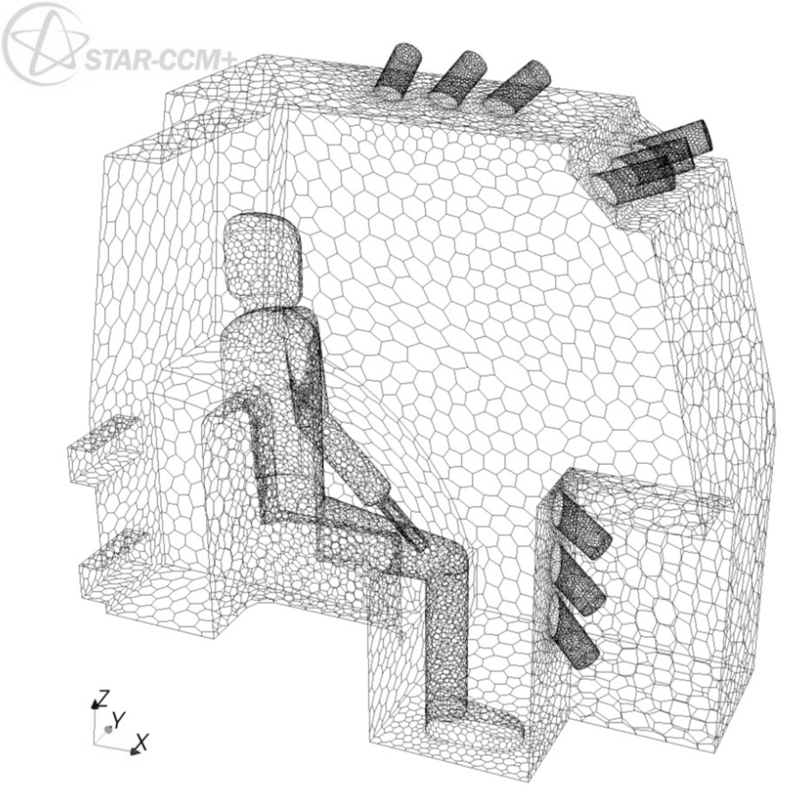

Fig. 2 Volume mesh of the simulation domain

Boundary conditions and simulation cases

All solid boundaries of the domain (manikin surface and cab walls) are taken as no-slip solid surfaces. Because the solar radiation was not accounted, windows were modelled as walls, with emissivity of 0.95. Walls temperature and initial interior air temperature was 30°C. These conditions presents the hot ambient, without the solar radiation.

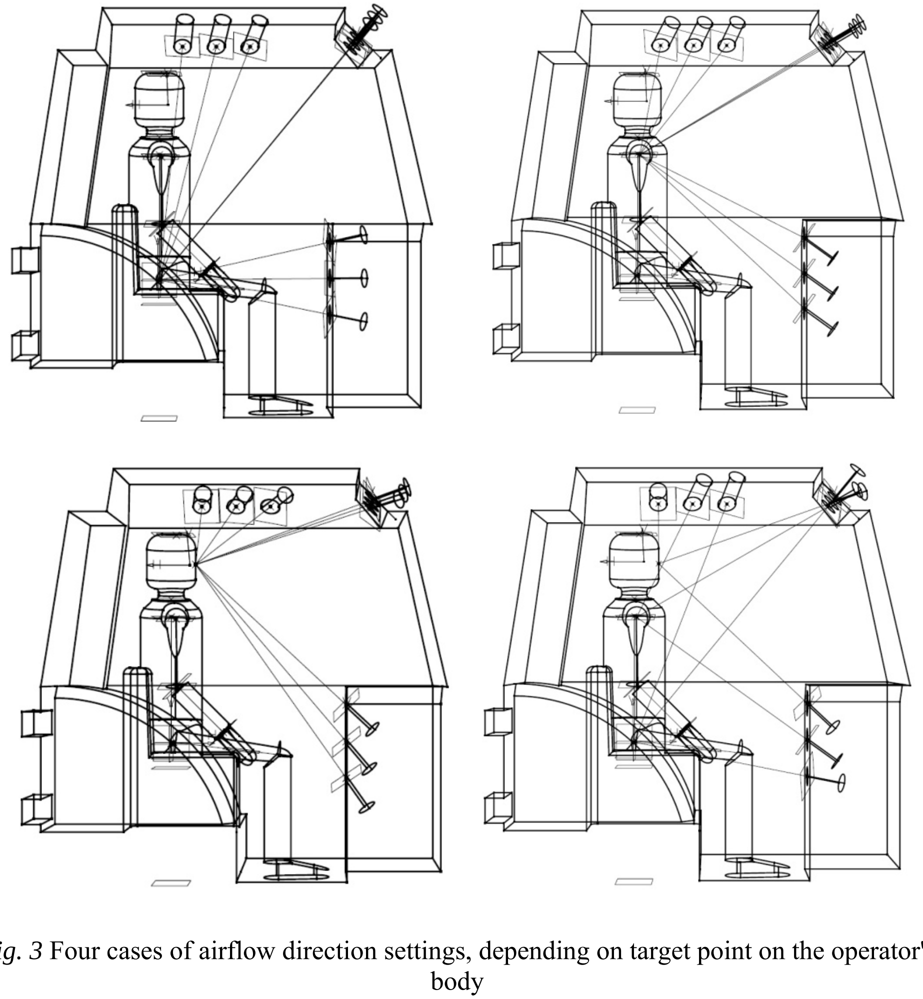

Fig. 3 Four cases of airflow direction settings, depending on target point on the operator's body

Nozzles are modelled as mass flow inlets, with air mass flow of 0.0633 kg/s for one-half of the cab in each simulation case. This corresponds to the total airflow of approximately 380 m^3/h, as a common value for tractor cab ventilation systems. Turbulence intensity in the inlet is set on 10%. Air temperature exiting the nozzles was 20°C. Outlets from the domain are positioned on the lower rear wall of the cab.

Apart from three different positions of ventilation nozzles, designated with IP, CF and CS (stands for "instrument panel", "ceiling front" and "ceiling side", respectively), there were four different airflow directions for every design. Nozzles were directed to the following target points: pelvis (H-point), chest, head and combination of them, where every nozzle was directed to the other target point, making twelve different simulation cases in total (figure 3). These settings are designated with "hp", "chest", "head" and "mix".

RESULTS AND DISCUSSION

The simulation results are presented in figures 4 to 7, separately for every case of airflow direction. The dotted line "Neutral" presents values of $t_{eq\ segm}$ and $t_{eq\ body}$ that corresponds to the neutral thermal sensation in summer conditions, according to ISO 14505-2.

Values of $t_{eq\ body}$ that have difference around one degree from the neutral value are those obtained in cases with instrument panel nozzles directed to the head, with lateral ceiling nozzles directed to the chest and in cases with front ceiling nozzles directed to the head or to the chest. The graphs as well as average value of absolute deviations showed that $t_{eq\ segm}$ values closest to the neutral are achieved in the cases with instrument panel nozzles directed to the head or to the chest. Highest differences in head and chest region $t_{eq\ segm}$, as the most sensitive parts, occurred mostly in the cases where nozzles were directed to the head. Chest is also overcooled when the front nozzles were directed to the pelvis. Although the results do not show clear relationship between equivalent temperature and air distribution system setting and design, there are obvious differences in total and segmental equivalent temperatures between the cases.

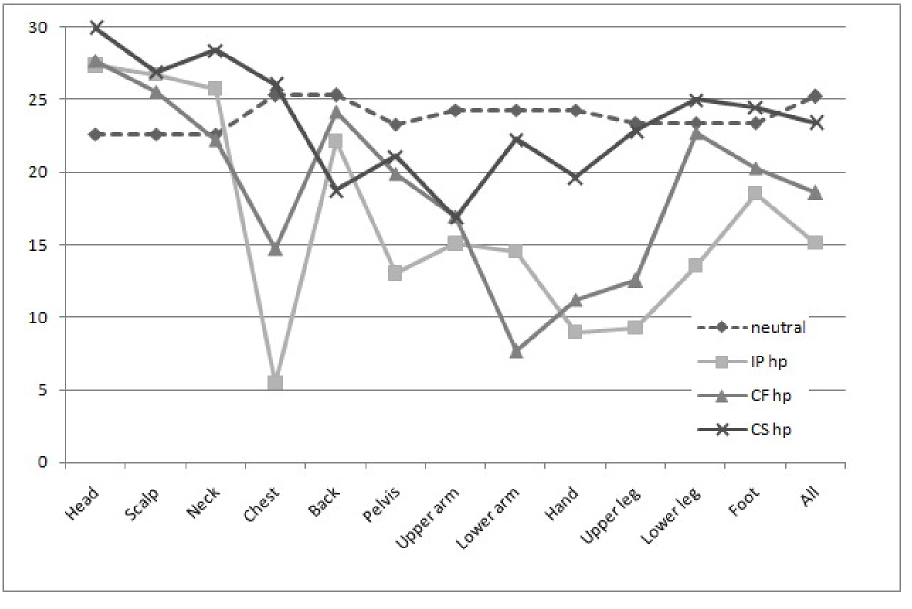

Fig. 4 Equivalent temperatures for airflow directed to the pelvis

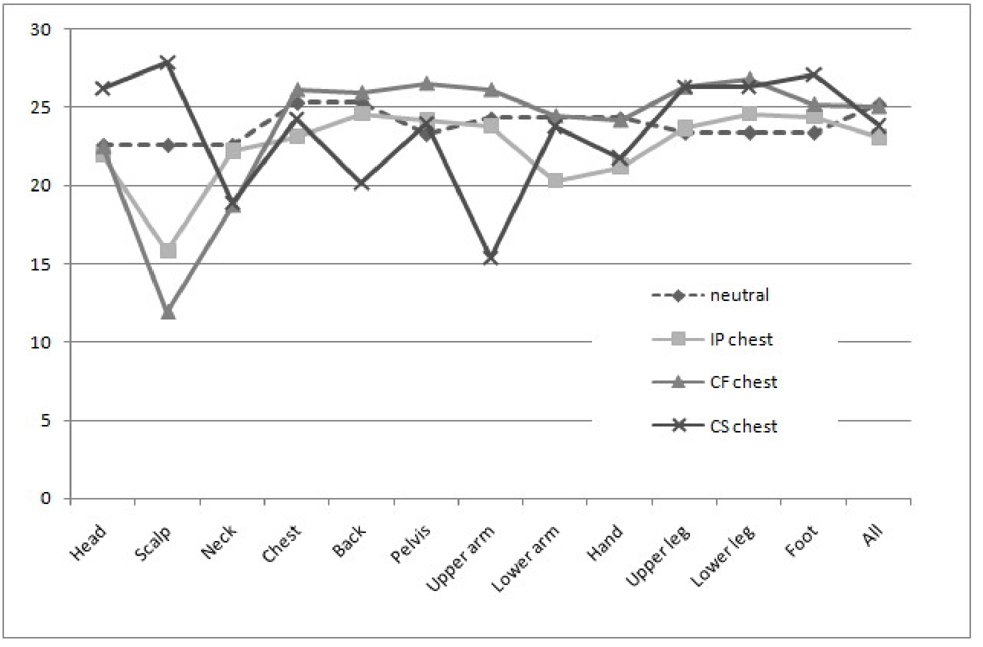

Fig. 5 Equivalent temperatures for airflow directed to the chest

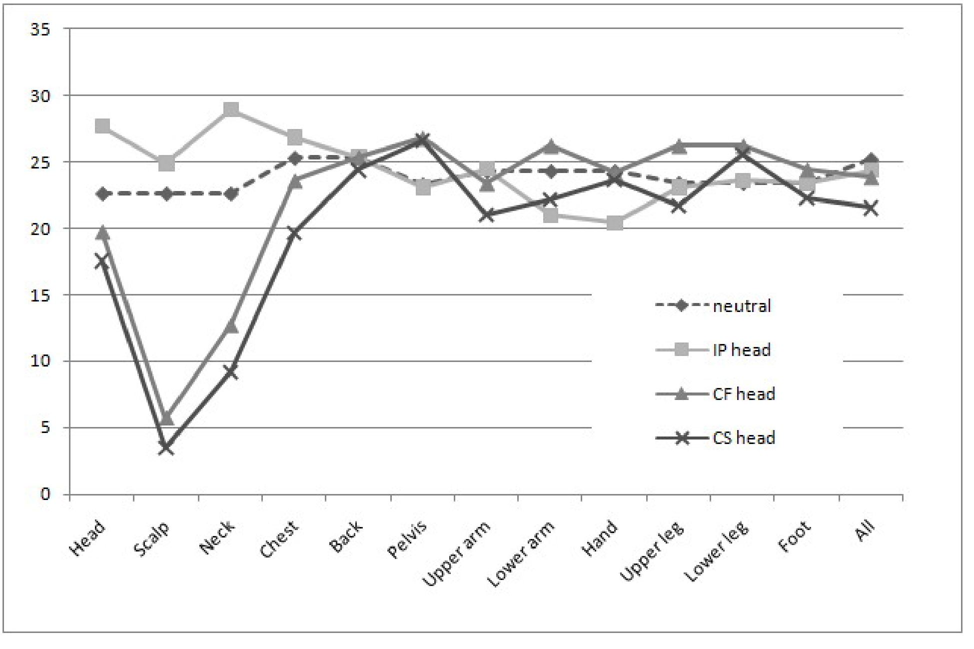

Fig. 6 Equivalent temperatures for airflow directed to the head

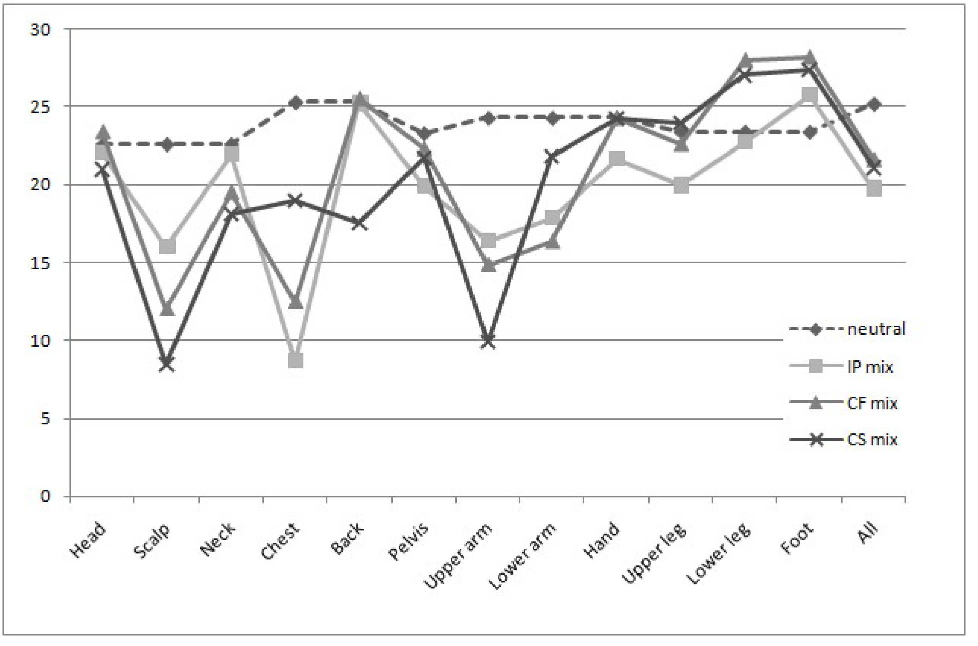

Fig. 7 Equivalent temperatures for combined directions of the airflow

CONCLUSIONS

The assessment of the influence of airflow direction on the thermal sensation was done using the equivalent temperature on the virtual model of the tractor cab with the operator. Segmental and whole-body equivalent temperatures were compared, under four different airflow direction of three different positions of air vents (nozzles), keeping both cooling load and boundary conditions constant. The results showed that thermal sensation can be very different from case to case, but influences of positioning of nozzles or airflow direction on operator's thermal sensation were not determined under these conditions. Though, the best results in relation to the neutral values of equivalent temperatures were achieved with the nozzles placed on instrument panel directed to the operator's head.

More information about significance of certain factors could be obtained by expanding the range of factor variations. However, there are almost unlimited possibilities of different settings of just one air distribution design, together with variety of ambient conditions, such as asymmetry, solar radiation and air humidity. In the future work this approach will be used for optimization of air distribution system and improvement of air-conditioning efficiency under standard boundary conditions, but with more variation in system design parameters.

ACKNOWLEDGMENT

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.373
Prethodno priopćenje
Preliminary communication

DESIGN CONCEPT CHOICE FOR AGRICULTURAL TRANSPORT VEHICLE BASED ON GIVEN TECHNICAL AND WORKING CONDITIONS

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SUMMARY

There are several arguments in favor of light agricultural transport vehicle to be used instead of tractor with trailer under appropriate circumstances. When amount of transported material enables it, usage of lower capacity vehicle contributes to fuel consumption and emission reduction. Further assets are compact design that enables better maneuverability, more even distribution of the load to the wheels which contributes to traction properties and soil protection, etc. It is therefore justified to work on development and improvement of vehicle specially developed for light agricultural transport. This paper deals with foundations of such development mostly from the point of view of the automotive engineering and agricultural transport. The basic idea is to design low-cost, easily maintained transport utility vehicle. In order to be able to focus on development approach, technical details and components choice, it is first necessary to closer define technical requirements and working conditions. Discussion follows about design criteria for relevant vehicle parts and systems.

***Key words**: utility vehicle, agricultural transport, vehicle concept development*

INTRODUCTION

Agricultural tractor with trailer can be considered as appropriate solution for transport of agricultural goods, when there is a significant amount of transported material. Still there are several arguments in favor of light agricultural transport vehicle development. When amount of transported material enables it, usage of lower capacity vehicle contributes to fuel consumption and emission reduction. Such cases are e.g. transport of restricted quantity of agricultural goods typical for small economies, transport for different logistic or service operations etc. Besides, compact design enables better maneuverability compared to tractor with trailer, above all on hill and mountain terrain. Further, load is more evenly distributed to the wheels, contributing to traction properties and soil protection.

Increased usage of ATV/UTV's in agriculture also shows that there is a need for versatile off-road vehicle which can be used both for light transport and some agrotechnical operations. Some examples of use are:

- transport of fresh fruits or vegetables to the green market;
- transport of spare parts and tires, bulky tools, building material, fuel etc;
- pesticide spraying, fertilizer / manure spreading;
- mowing and material loading;
- soil cultivation in fruit, vegetable and wine growing;
- and many more.

Another important point is contribution of such vehicle to the working and traffic safety, for both tractors and ATV's are known for being involved in significant number of road and off-road accidents [2]. Design properties of agricultural transporter can increase driving safety and enable better protection of passengers in case of accident.

Still there are only a small number of such vehicles designed specifically for use in agriculture. Therefore it is justified to further develop agricultural transport vehicles, in order to satisfy needs and financial capabilities of more wide range of potential users.

In this paper preliminary design considerations for new design of such vehicle are given. The basic idea is to design low-cost, easily maintained transport utility vehicle. Since vehicle development from start is a very complex process including large number of parameters that should be determined and matched to each other, comprehensive treatment of the topic in the scope of one paper is impossible. Therefore here the main guidelines for further development process will be defined, mainly from the point of view of automotive engineering, i.e. only systems for vehicle motion are considered. Defining systems for carrying out different operations requires different approach and will be carried out separately.

GENERAL VEHICLE CONCEPT AND MEASURES

In order to discuss vehicle systems and components, it is necessary to first provide basic overview of the vehicle concept, dimensions and weights. Based on analysis that will be published separately from this paper, basic vehicle parameters are determined as shown in Table 1 and 0. For determination of vehicle design properties it has to be taken into account that the main purpose of the vehicle is light transport in agriculture, predominantly on the hill terrain and in off-road conditions. Beside this, vehicle should be capable of traveling at speed of 45 km/h on paved roads, providing sufficient comfort for driver and possible passengers.

It should be mentioned at this place that this utility vehicle should also be capable of carrying out different agricultural operations, which assumes attachments and implements mounting possibility. For this reason, vehicle has to be equipped with a changeable bodywork. This topic will be discussed in more details in separate publication.

In order to lower the costs and shorten the time of the prototype development, components of existing off-road and road vehicles should be used wherever appropriate.

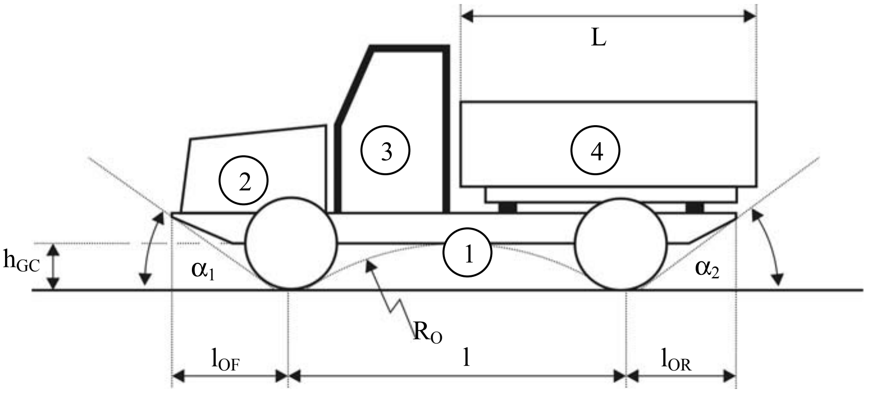


Figure 1 Basic vehicle layout (dimensions according to Table 1): 1 – carrying platform, 2 – engine compartment, 3 – protective frame for passengers, 4 – changeable bodywork; l – wheelbase, l_{OF}, l_{OR} – front and rear overhangs, α_1, α_2 – front and rear approach angles, h_{GC} – ground clearance, R_O – longitudinal obstacle radius

Table 1 Basic vehicle parameters

Top speed	Should not exceed 45 km/h, to simplify vehicle certification process and because of driving license demands
Gross vehicle mass	Approx. 2500 kg
Payload	Approx. 1500 kg
Wheelbase l	2000-2500 mm
Approach angles α_1, α_2	At least 45°
Ground clearance	250 - 350 mm
Cargo box length	Approx. 2m
Front and rear overhangs l_{OF} and l_{OR}	Have to be chosen according to approach angle values. Sloped edges of the lower side of the vehicle can help to further increase approach angles as shown in Fig. 1.
Longitudinal obstacle radius	Value depends on wheelbase, ground clearance and wheel size. Shorter wheelbase provides better off-road mobility, but at the expense of comfort. Exact values of these parameters have to be determined during the vehicle development.

PROPULSION UNIT CHOICE

For the first stage of development, conventional powertrain with IC engine is considered to be the most acceptable solution. Both CI and SI engines should be taken into consideration in order to utilize available alternative fuels such as biodiesel, LPG, CNG etc. In later development phases, alternative powertrain concepts will possibly also be considered, such as electric drive, hybrid drive or energy recuperation systems.

Choice of IC engine and its systems has to be made according to their ability to function effectively under specific working conditions. Above all, systems for lubrication and fuel intake have to be able to work properly while the vehicle operates at a steep slope. Since intake air in agricultural environment can contain considerable quantities of dust particles, it is of vital importance to use appropriate air cleaner.

Engine capacity has to match requested vehicle performance characteristics. Preliminary consideration assumes assessment of power needed to overcome motion resistance. Since maximum velocity is low enough to neglect aerodynamic forces, in pure transport mode at constant velocity only the following resistance components act:

$$\text{Rolling resistance, } F_f = f \cdot G \cdot \cos\alpha \quad (1)$$

$$\text{Grade resistance, } F_\alpha = G \cdot \sin\alpha \quad (2)$$

where:

f – rolling resistance coefficient, G – gross vehicle weight, α – grade angle

f = 0,015 – at firm ground [3, 6]

f = 0,1 – average value for dirt road [7]

In order to assess vehicle performance characteristics on the basis of available engine power, Table 2 shows power on traction wheels needed to overcome motion resistance on hard surface in dependence of velocity, for several values of the road longitudinal inclination.

Table 2 Dependence of the power needed at traction wheels on velocity, for different uphill grade values on a firm surface; α - uphill grade, v – velocity, P – power needed at traction wheels

	v [km/h]				
	10	20	30	40	50
α [%]	P [kW]				
0	1,2	2,5	3,7	4,9	6,1
5	5,3	10,6	15,9	21,2	26,5
10	9,3	18,7	28,0	37,4	46,7
15	13,3	26,7	40,0	53,3	66,7

On the soft ground, i.e. in off-road driving conditions, highest possible slope is much more relevant than speed. Table 3 shows required power to climb certain slope on the soft ground, providing the speed is chosen to be constant at arbitrary value v=5km/h.

Table 3 Power required at traction wheels for different uphill grade values on a dirt road, for presumed speed v=5km/h

Uphill grade α [%]	10	20	30	40	50	100
Needed power P [kW]	8,1	12,0	15,7	19,0	21,9	31,8

For the sake of simplification, transmission power losses have not been included in the calculation, since at this point needed engine power should only be approximately assessed.

There are no unambiguous criteria to select exact value of required engine power, but assessment can be made on the basis of requirement that vehicle should be capable of reaching appropriate speed not only on the level ground but also while driving uphill. This is important both because of transport capacity and traffic safety. Bearing this in mind, calculation results indicate that engine should be chosen so that maximum available power lies approximately between 25 and 35 kW. Ability to develop satisfactory motion velocity while climbing a hill on a motorway will at the same time provide adequate acceleration performance characteristic. For final choice of the engine it is, however, necessary to analyze engine types available on the market. Beside maximum power, other very significant choice criteria are:

- fuel consumption
- reliability and expected lifetime
- maintenance suitability, service network and spare parts availability
- suitability of intake and lubrication systems for work in off-road conditions and particle-polluted environment
- emission of exhaust gasses, noise and vibration
- suitability for alternative fuels, etc.

TRANSMISSION LAYOUT

Off-road transport utility vehicle has, by its nature, to be equipped with an all-wheel drive transmission. The first thing is to make choice between:

- all-time AWD, and
- part-time AWD.

From these two concepts, part time AWD represents more convenient solution for following reasons:

- Main purpose of AWD in this case is increased off-road mobility, and not motorway driving performances

- Part-time AWD is capable of reaching slightly better fuel consumption on firm ground, if appropriate clutch for disengaging front hubs are provided
- Transfer case is more simple and cheap to build than a centre differential
- No additional lock is needed as in the case of centre differential in all-time AWD;
- Transmission and therefore overall vehicle design is more flexible

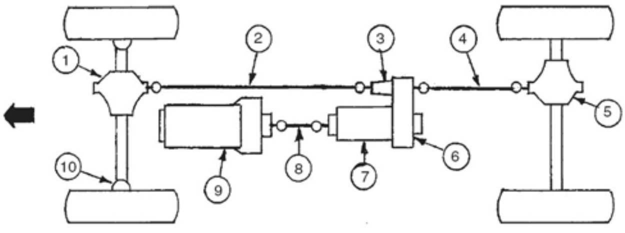


Figure 2 General arrangement of a part-time four-wheel drive system for off-road vehicles [5]: 1,5- final drive, 2,4,8-propeller shaft, 3-FWD clutch, 6-transfer gears, 7-main gearbox, 9-engine and clutch, 10-CV joints

General arrangement of a part-time AWD system is shown in 0 [5]. Final choices for individual components and their layout have to match other vehicle parameters, so they have to be determined during development process. The most important criteria that have to be taken into consideration are, amongst all, the following:

- Shortest overall transmission ratio should enable vehicle to climb 100% uphill grade, i.e. 45° angle, which is a common requirement for terrain vehicles;
- Gearbox should have increased number of ratios in order to fully utilize available engine power; these have to be arranged for transport, i.e. to follow geometrical gear steps [4];
- Suitability of available CVT gearboxes should also be analyzed;
- Gear ratios should contain one creeping ratio;
- Front and rear differential lock should be mechanical, with manual engagement, since a number of users claim insufficient effectiveness of automatic systems;
- Etc.

STEERING SYSTEM

Steering system properties contribute much to the overall assessment of vehicle performances. For the steering system layout two basic concepts can be considered:

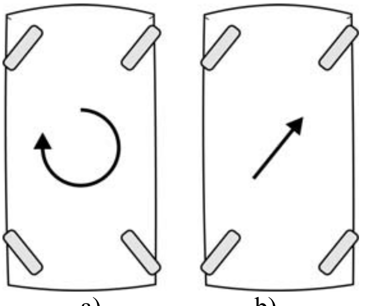
- Articulated chassis, and
- Ackermann-steering.

Although articulated chassis can often be considered as more appropriate solution for off-road utility vehicle [1], decision was made to use Ackermann-steering for agricultural transporter for the following reasons:

- Carrying frame is more simple and cheaper to build;
- Vehicle has better stability at lateral slope;
- Design modularity and afterward changes are easier to carry out;

Vehicle primary task is transport of goods at certain distances, which in general does not require extreme maneuverability. This fact, together with mentioned properties, further justifies avoiding of articulated chassis layout. If, however, in particular cases user demand for higher maneuverability exists (e.g. work with front loader, frequent use at constrained maneuver space etc.), rear-axle Ackermann steering can be offered as an option. In that case following solutions are possible (0):

- Turning front and rear wheels in opposite directions, in order to decrease turning radius;
- Turning front and rear wheels in same direction, („crab-motion“); this approach is useful when working at lateral slope, in order to compensate wheel lateral slip caused by lateral force at vehicle CG; it can also be useful for some operations (e.g. filling-in ditches).



a) b)

Figure 3 Four-wheel Ackermann steering: maneuverability increase (a) and sidelong motion (b)

SUSPENSION, WHEELS AND TIRES

For a vehicle that is developed from blank sheet, there are a large number of possible suspension layouts. There are, however, no unambiguous choice criteria. Independent suspension can improve off-road ability and driver comfort, especially by higher velocity. Rigid axles also have good characteristics for off-road mobility, can also contribute to more simple carrying structure and building costs decrease. In accordance with development principles, final choice demands more detailed analysis of solutions available on the market. Analysis should comprise both influence on vehicle characteristics and economical effects.

Dimensions of wheels and tires should be chosen in accordance with fact that different users may have different requirements regarding types of ground vehicle rides on. Wheel size should therefore enable mounting of different kinds of tires, including both agricultural and different off-road tread patterns. Some patterns are shown as example in 0 [8]. Market analysis shows that significant percent of SUV's and terrain vehicles are equipped with the wheels from 15" – 17", which is at the same time dimension for which diverse low-pressure lugged agricultural tires are available. Greater wheels, e.g. 20", can be offered as an option. Additional option for twin-wheels mounting can contribute soil protection and traction properties on more susceptible agricultural terrains.

Figure 4 Agricultural and off-road tread pattern examples [8]

BRAKING SYSTEM

Motion of full loaded vehicles at steep slopes, as well as its presence on public roads, are the conditions demanding divided-line hydraulic brake system acting on all wheels. In order to increase safety for driving up or down steep slopes at slippery road condition, emergency brake should also act at all 4 wheels.

Discussing braking system, it should be highlighted at this point that transport in hill terrain, which is the main purpose of the vehicle, provides optimal background for use of kinetic and gravitational potential energy recuperation system. Although development and use of such system is not a part of first vehicle prototype development schedule, it should certainly be an important topic of future analysis.

CONCLUSIONS

It is shown that development of light agricultural transport utility vehicle is justified by the fact that use of such vehicle can contribute to energy efficiency, soil protection and both working and traffic safety. At the same time such vehicle can also be used at building sites, for communal transport, as recreational vehicle etc. Basic description of preliminary design considerations is given. Choice criteria for vehicle mechanical systems based on technical and working conditions are stated. It is determined that engine power should be approximately 25-35 kW, in order to satisfy needs of transport capacity and traffic safety. Engine unit has to be chosen taking into account other criteria such as fuel consumption and emission, reliability, suitability to work under specific off-road conditions etc. In later phases of research potential of hybrid drive use should be investigated.

Transmission should enable part-time all-wheel drive. Final choice of the gearbox and overall transmission layout is to be made only when the final engine choice is made. Steering system should be of Ackermann-type, with optional additional rear-wheel steering. Wheel dimension has to enable mounting of different agricultural and off-road tires. Suspension system layout choice demands more detailed analysis approach. Further analysis of the market available components follows, and their final choices.

Vehicle that is primarily designed for light agricultural transport should also be capable of carrying out other agricultural taska. Therefore it is necessary to provide technical possiility for vehicle to be equipped by appropriate implements and additional components. This approach will be subject of further research.

ACKNOWLEDGMENT

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Preliminary communication

RESEARCHES ON THE DEVELOPMENT OF AN EQUATION FOR THE CONTACT AREA CALCULUS FOR AGRICULTURAL TIRES

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SUMMARY

Tire is an important constitutive element for agricultural vehicles, due to its multiple functions: ensure proper adhesion to the rolling track, safety and resistance to high-speed movement, attenuate the shocks caused by uneven rolling tracks, take the loads distributed on wheels, contribute to the comfort of passengers or operators. Through tire contact area, agricultural vehicle and rolling track are linked together. In tire contact area are applied the traction forces for vehicle propulsion, braking, normal reactions, etc. In this paper was developed a complex mathematical model to generate the contour of the contact area between the tire and rolling track and for the calculus of the surface of contact area, depending of tire geometry and on the deflection characteristics of the tire, which allows the exploitation of pneumatic tire for agricultural land vehicles. Theoretical studies and experimental researches developed within this paper emphasized the fact that 2-D contact area is elliptical when tire deflection is small, but it becomes rectangular with curved edges as the deflection increase. The model predictions were verified by means of the experimental results obtained using the tires of an agricultural trailer. Simulation studies indicated that the elaborated equations can be useful for predicting the details of contact geometry under varying load, inflation pressure, and tire geometry conditions.

Key words *Wheel, tire, agricultural land vehicle, contact area*

INTRODUCTION

The term "contact area" refers to the portion of wheel or tire in contact with the supporting surface [9], which is an important indicator of the load-carrying capability of the tire. Tires have the following functions for a land vehicle: attenuate the shocks caused by uneven rolling tracks, ensure proper adhesion to the rolling track, safety and resistance to high-speed movement, takes the loads distributed on wheels, and contribute to the comfort of operators or passengers.

Tire inflation pressure has influence on the shape of the contact surface between tire and soil, the distribution of stresses in the soil and thus, and on the phenomenon of soil compaction. Also, tire inflation pressure has a significant influence on the rolling and adhesion characteristics of the wheels, being a decisive factor on the fuel consumption required for the movement of agricultural vehicles (Gill and Vanden Berg, 1968; Wulfsohn, 1987; Upadhyaya, 1990). Tire performances for various conditions of the rolling track, at different dynamic loads and inflation pressures are very important parameters for the increase of efficiency in tire exploitation. Upadhyaya (1990) found that in addition to tire geometry, the parameters of rolling track and loading, rolling track – tire contact area were important parameters which influence the tractive capacity of tires [8]. Abeels (1976) studied the effect of tire load and tire construction parameters on width of tire enlargement, length of contact track, and its shape [1, 8]. Komandi (1976) [3] established empirical relationships for tire contact width, contact length, and contact area [8]. Also, very important are the contributions of Koolen and Kuipers (1983) [4] for the elaboration of some expressions for the elliptical contact area between tire and a hard surface.

"Static contact area" represents the contact area on rigid or deformable surfaces when the tire is statically loaded through its rim without any forward movement [9].

Figure 1 illustrates the principal parameters of the tire. *Tire diameter* (overall diameter) is twice the section height of a new tire, including 24-hour inflation growth, plus the nominal rim diameter. This overall unloaded diameter can be obtained from tire data handbooks, which are available from off-road tire manufacturers. *Tire static loaded radius* is the dimension measured from the axle centreline to the ground, when the tire is under the load.

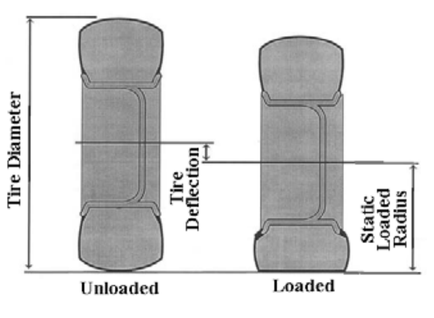

Fig. 1 Vehicle tire, unloaded and loaded

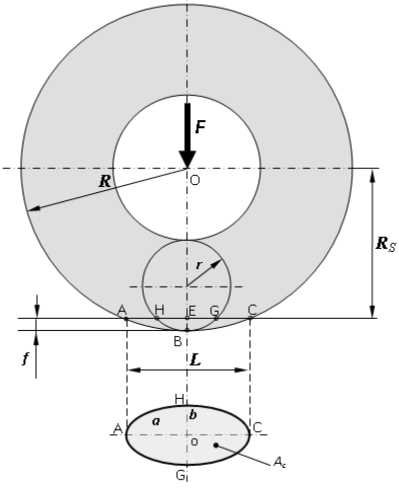

Fig. 2 Tire deformation under the action of an external load

THEORETICAL ELEMENTS

According to Hedekel's equation (Fig. 2), tire deformation is given by the relationship [4]:

$$f = \frac{F}{2 \cdot \pi \cdot p_i \cdot \sqrt{R \cdot r}} \text{ [mm]} \tag{1}$$

where: F – vertical load on the wheel, [N]; p_i – air pressure inside the tire, [MPa]; R – free radius of the wheel, [mm]; r – radius of tire rolling path in cross section, [mm].

Static tire radius is given by:

$$R_s = R - f \text{ [mm]} \tag{2}$$

and the lenght of the contact chord is:

$$L = 2 \cdot \sqrt{R^2 - R_s^2} \text{ [mm]} \tag{3}$$

The empirical model of calculus for the contact area with the soil for agricultural tires proposed by Komandi [3] is:

$$\boxed{A_{soil} = c \cdot F^{0.7} \cdot \sqrt{\frac{b}{D}} \cdot p_i^{-0.45}} \text{ [mm}^2\text{]} \tag{4}$$

where: c –constant; F –wheel load, (N); b –tire vidth, (mm); D –tire diameter, (mm); p_i – inflation pressure, (MPa). Constant c for different substrates has following values (Komandi, 1976): c=0.3-0.32 for rather bearing soil, c=0.36-0.38 for sandy field, and c=0.42-0.44 for loose sand.

3D coordinates of a random point M found on both the tire and on the outline of the contact area can be determined according to the equations [8]:

$$\begin{cases} x_M = R_2 \cdot \sin\phi \\ y_M = \left[R_1 - R_2 \cdot (1 - \cos\phi)\right] \cdot \sin\theta \\ z_M = \left[R_1 - R_2 \cdot (1 - \cos\phi)\right] \cdot \cos\theta \end{cases} \tag{5}$$

where: R_1 - overall tire radius, and R_2 - tread radius.

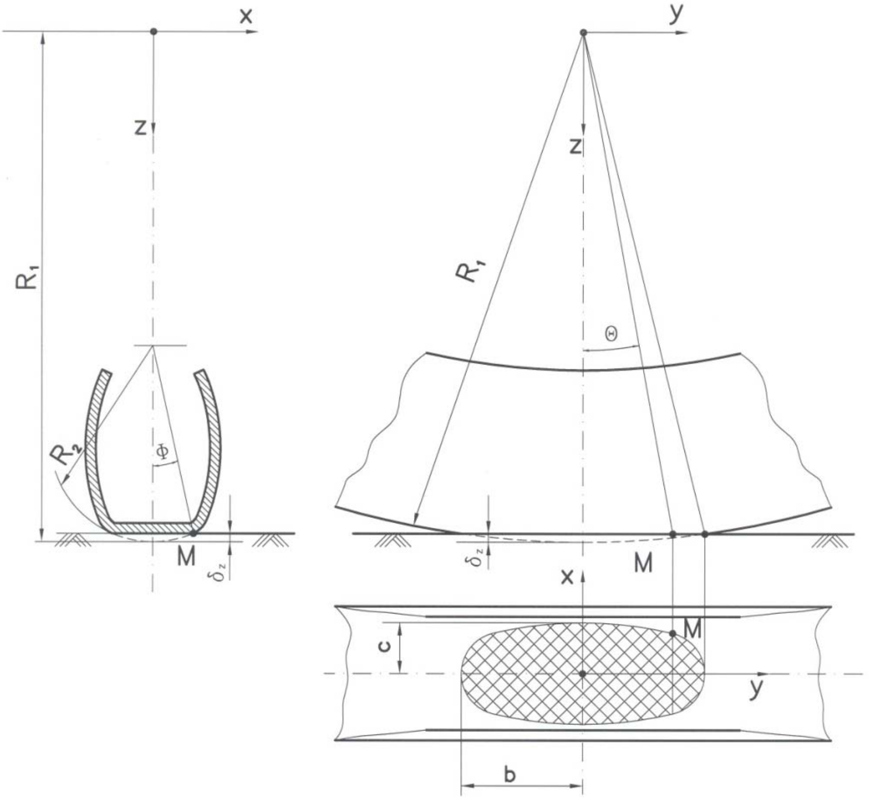

Fig. 3 Tire geometry

On a hard surface (Fig. 3), under the action of an external load *F*, tire deforms on direction *z* with δ_z, while the outline of the contact area can be described by the points of intersection with plane $z = R_1 - \delta_z$, respectively [8]:

$$y^2 + z^2 = (R_1 - R_2 + R_2 \cdot \cos\phi)^2 \Leftrightarrow y^2 + (R_1 - \delta_z)^2 = (R_1 - R_2 \cdot \cos\phi)^2 \tag{6}$$

or:

$$R_2 \cdot \cos\phi = \sqrt{(R_1 - \delta_z)^2 + y^2} - (R_1 - R_2) \tag{7}$$

By squaring equation (7), it is found that:

$$R_2^2 \cdot \cos^2\phi = (R_1 - \delta_z)^2 + y^2 + (R_1 - R_2)^2 - 2 \cdot (R_1 - R_2) \cdot \sqrt{(R_1 - \delta_z)^2 + y^2} \tag{8}$$

However, the left term can also be written as:

$$R_2^2 \cdot \cos^2\phi = R_2^2 \cdot \left(1-\sin^2\phi\right) = R_2^2 - R_2^2 \cdot \sin^2\phi \tag{9}$$

If:

$$x = R_2 \cdot \sin\phi \tag{10}$$

then:

$$R_2^2 \cdot \cos^2\phi = R_2^2 - x^2 \tag{11}$$

after replacing in equation (8), it results:

$$R_2^2 - x^2 = \left(R_1-\delta_z\right)^2 + y^2 + \left(R_1 - R_2\right)^2 - 2\cdot\left(R_1-R_2\right)\cdot\sqrt{\left(R_1-\delta_z\right)^2 + y^2} \tag{12}$$

Respectively [8]:

$$R_2^2 - \left(R_1-R_2\right)^2 - \left(R_1-\delta_z\right)^2 = x^2 + y^2 - 2\cdot\left(R_1-R_2\right)\cdot\left(R_1-\delta_z\right)\cdot\sqrt{1+\left(\frac{y}{R_1-\delta_z}\right)^2} \tag{13}$$

If following condition is accomplished:

$$\frac{y}{R_1-\delta_z} << 1 \tag{14}$$

approximation can be done [8]:

$$\sqrt{1+\left(\frac{y}{R_1-\delta_z}\right)^2} \cong 1 + \frac{1}{2}\cdot\left(\frac{y}{R_1-\delta_z}\right)^2 \tag{15}$$

After replacing in equation (13) and proper reductions it results that:

$$x^2 + y^2 - \delta_z\cdot\left(2\cdot R_2 - \delta_z\right) - \left(R_1^2 - R_1\cdot R_2 - R_1\cdot\delta_z + R_2\cdot\delta_z\right)\cdot\frac{y^2}{\left(R_1-\delta_z\right)^2} = 0 \tag{16}$$

respectively:

$$\delta_z \cdot (2 \cdot R_2 - \delta_z) = x^2 + y^2 \cdot \left[1 - \frac{R_1^2 - R_1 \cdot R_1 \cdot \delta_z + R_2 \cdot \delta_z}{(R_1 - \delta_z)^2} \right] \tag{17}$$

or [8]:

$$\delta_z \cdot (2 \cdot R_2 - \delta_z) = x^2 + y^2 \cdot \frac{R_2 - \delta_z}{R_1 - \delta_z} \tag{18}$$

For [8]:

$$\begin{cases} c^2 = \delta_z \cdot (2 \cdot R_2 - \delta_z) \\ b^2 = \dfrac{R_2 - \delta_z}{R_1 - \delta_z} \end{cases} \tag{19}$$

equation (18) becomes:

$$\boxed{c^2 = x^2 + b^2 \cdot y^2} \tag{20}$$

respectively:

$$\boxed{\frac{x^2}{c^2} + \frac{y^2}{\left(\frac{c}{b}\right)^2} = 1} \tag{21}$$

Equation (21) describes an ellipse with large semi axis (*c/b*) and small semi axis *c*. If *c* is larger than half of tire width, then the contact patch outline will also be composed of straight lines, as shown in figure 4 [8,9]:

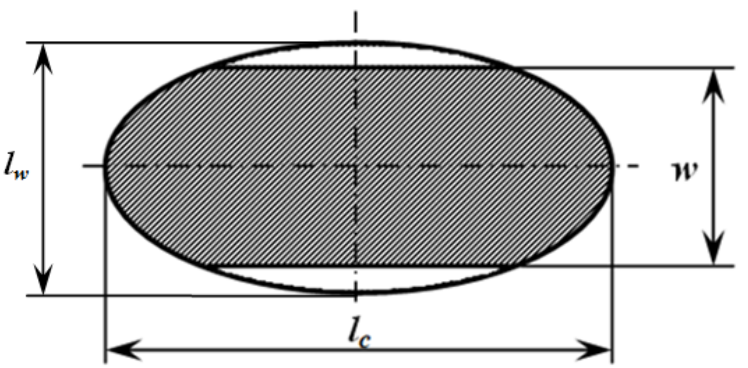

Fig. 1 Tire deformation on the rigid surface [8]

Using equation (21), the contact length l_c is obtained:

$$l_c = 2 \cdot \frac{c}{b} = 2 \cdot \sqrt{\delta_z \cdot (2 \cdot R_2 - \delta_z) \cdot \frac{R_1 - \delta_z}{R_2 - \delta_z}} = 2 \cdot \sqrt{\frac{\left(2 \cdot R_2 \cdot \delta_z - \delta_z^2\right) \cdot (R_1 - \delta_z)}{R_2 - \delta_z}} \tag{22}$$

thus [8]:

$$\boxed{\frac{l_c}{2 \cdot R_1} = 2 \cdot \sqrt{\frac{\delta_z}{2 \cdot R_1} \cdot \left(1 + \frac{\delta_z}{4 \cdot R_2} - \frac{\delta_z}{2 \cdot R_1}\right)}} \tag{23}$$

Knowing tire diameter $D = 2 \cdot R_1$, and if following conditions are accomplished [8]:

$$\begin{cases} \dfrac{\delta_z}{4 \cdot R_2} << 1 \\ \dfrac{\delta_z}{2 \cdot R_1} << 1 \end{cases} \tag{24}$$

equation (23) can be written as [8]:

$$\boxed{\frac{l_c}{2 \cdot R_1} \cong 2 \cdot \sqrt{\frac{\delta_z}{2 \cdot R_1}} \quad \Leftrightarrow \quad \frac{l_c}{D} \cong 2 \cdot \sqrt{\frac{\delta_z}{D}}} \tag{25}$$

Equation (23) corresponds to the situation in which a random point on the tire near the contact patch moves during static deformation after vertical direction, and equation (25) describes the motion of the same point during deformation but after normal direction on tire (Fig. 5).

Also, by considering figures 3 and 4, contact width is determined:

$$l_w = 2 \cdot c = 2 \cdot \sqrt{\delta_z \cdot (2 \cdot R_2 - \delta_z)} \tag{26}$$

so [8]:

$$\boxed{\frac{l_w}{2 \cdot R_2} = 2 \cdot \sqrt{\frac{\delta_z}{2 \cdot R_2} \cdot \left(1 - \frac{\delta_z}{2 \cdot R_2}\right)} = 2 \cdot \sqrt{\frac{\delta_z}{2 \cdot R_2}} \cdot \left(1 - \frac{\delta_z}{4 \cdot R_2}\right)} \tag{27}$$

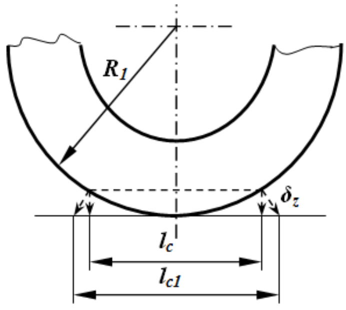

Fig. 5 Two possible situations for tire deformation

If following condition is accomplished [8]:

$$\frac{\delta_z}{4 \cdot R_2} << 1 \tag{28}$$

equation (27) can be written as [8]:

$$\boxed{\frac{l_w}{2 \cdot R_2} \cong 2 \cdot \sqrt{\frac{\delta_z}{2 \cdot R_2}}} \tag{29}$$

Still, if l_w is higher than track width, then contact width is w.

Equation (27) applies to the case in which a point on the tire moves down on vertical direction, and equation (29) corresponds to the case in which the same point on the tire moves along the normal direction on tire surface.

If the contact area is elliptical, its surface can be calculated as [8]:

$$\boxed{A_c = \pi \cdot \frac{l_c}{2} \cdot \frac{l_w}{2} = \frac{\pi}{4} \cdot l_c \cdot l_w} \tag{30}$$

and for $l_w > w$, the area of contact patch can be calculated using equation [8]:

$$\boxed{A_c = \frac{\pi}{4} \cdot l_c \cdot l_w - 2 \cdot \int_{\frac{w}{2}}^{c} \int_{-y}^{y} dx \cdot dy = \frac{\pi}{4} \cdot l_c \cdot l_w - 4 \cdot \int_{\frac{w}{2}}^{c} \int_{0}^{\left(\frac{c}{b} \cdot \sqrt{1 - \frac{x^2}{c^2}}\right)} dx \cdot dy} \tag{31}$$

MATERIALS, METHODS AND RESULTS

For experimental tests was used a monoax agricultural trailer, type TR2000 (Fig. 6). Loading capacity of this trailer is 2000 kg and the mass of 650 kg, being used for transport operation in wine culture and fruit farming or on public roads, in aggregate with a 45 HP tractor. The trailer is equipped with 10.00/75-15.3 12PR agricultural tires (Fig. 7).

During the tests, the trailer was loaded with metallic weights so that the load on wheel was kept constant. Weight on wheel value was 805 kg and it was measured using an electronic ladometer. Contact patch with the rigid surface was recorded by printing it on paper sheets and indigo.

Fig. 6 Monoax agricultural trailer, model TR2000

Fig. 7 Agricultural tire 10.00/75-15.3 12PR

For various measurements performed during testings, the load on wheel was kept constant while inflation pressure was modified. Measurements were taken for following inflation pressures: 0.1; 0.125; 0.15; 0.175; 0.2; 0.225; 0.25 MPa.

Figure 8 presents the tracks left by the tire on the rigid rolling surface, which were recorded on indigo paper. The surface of each of these real contact tracks was measured with a mechanical planemeter. Figure 8.a shows the contact track for the unloaded trailer when inflation pressure was 0.25 MPa, while in figures 8(b,...., h) are presented the tracks for loaded trailer, whose characteristics are given in table 1.

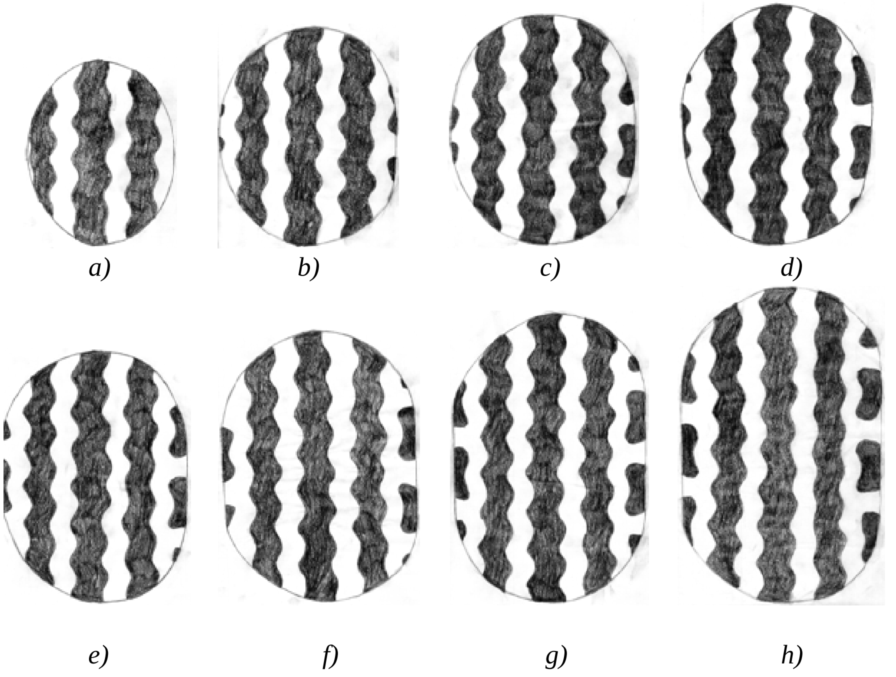

Fig. 8 Real contact track between tire and rigid rolling track

Table 1 – Size characteristics of contact track

p_i [MPa]	f [mm]	R_s [mm]	L [mm]	A_1 [mm^2]	l_c [mm]	l_w [mm]	A_2 [mm^2]	A_3 [mm^2]	***Fig.***
0.1	56.92	333.07	405.77	72228.18	459.108	215.040	77500.71	45120	8.h
0.125	45.54	344.45	365.78	65109.49	399.172	197.656	61935.81	39710	8.g
0.15	37.95	352.04	335.63	59742.9	359.060	183.600	51750.1	36950	8.f
0.175	32.53	357.46	311.87	55512.88	329.476	172.043	44497.14	33200	8.e
0.2	28.46	361.53	292.52	52068.6	306.377	162.364	39049.55	31360	8.d
0.225	25.30	364.69	276.37	49193.93	287.645	154.120	34800.57	29690	8.c
0.25	22.77	367.22	262.62	46747.63	272.033	146.997	31390.76	26730	8.b

Table 1 gives the size characteristics of contact track for the same load on the wheel (805 kg) and various inflation pressures. The meaning of terms given in columns are:

- *f* – tire deformation, calculated using equation (1);
- R_s – static tire radius, calculated using equation (2);
- *l* – lenght of the contact cord, calculated using equation (3);
- A_1 – theoretical area of contact track, calculated as the area of a rectangle: $A_1=L\cdot w$;
- l_c – contact length, calculated using equation (22);
- l_w – contact width, calculated using equation (26);
- A_2 – theoretical area of contact track, calculated as the area of an ellipse, (Eq. 30);
- A_3 – real area of contact track, obtained experimentally and measured with mechanical planemeter;
- *Fig.* – corresponding contact track from figure 8.

Figure 9 shows an comparative analysis of the values of theoretical contact areas A_1 and A_2, respectively real area A_3, according to table 1.

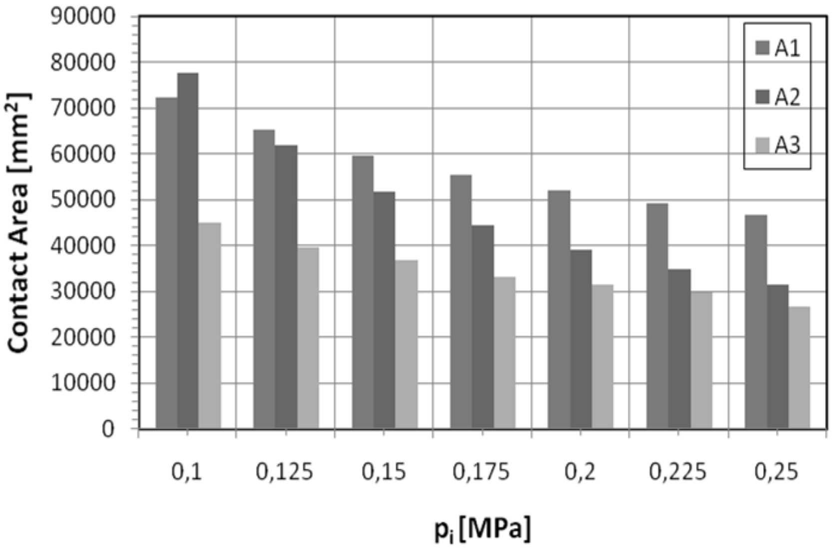

Fig. 9 Comparative analysis of the contact area between tire and rolling track, depending on tire pressure

Figure 10 illustrates the influence of tire pressure on the dimensional characteristics of the wheel (Figure 2), respectively tire deformation (Eq. 1), static radius R_s (Eq. 2) and the length of contact chord *L* (Eq. 3), for the wheel of an agricultural trailer model TR2000.

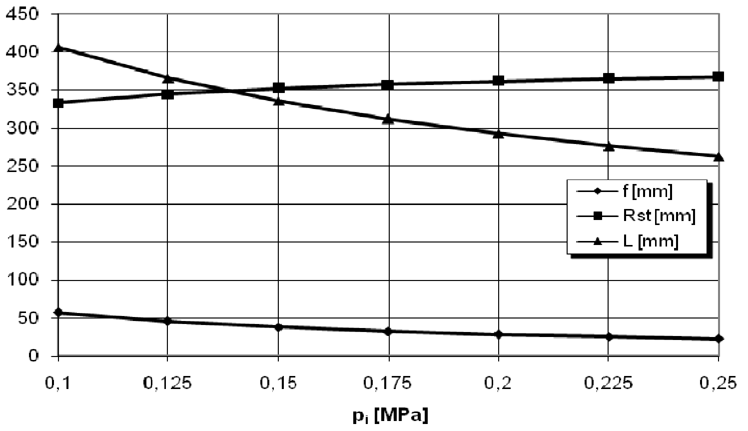

Fig. 10 Influence of tire pressure on the dimensional characteristics of the 10.00/75-15.3 12PR tire

Figure 11 presents the effect of inflation pressure on the contact area and on the shape of the ellipsoidal outline of contact track. There are presented the theoretical ellipses drawn according to equation (21) in a single scale disk, representing ¼ of the contact track.

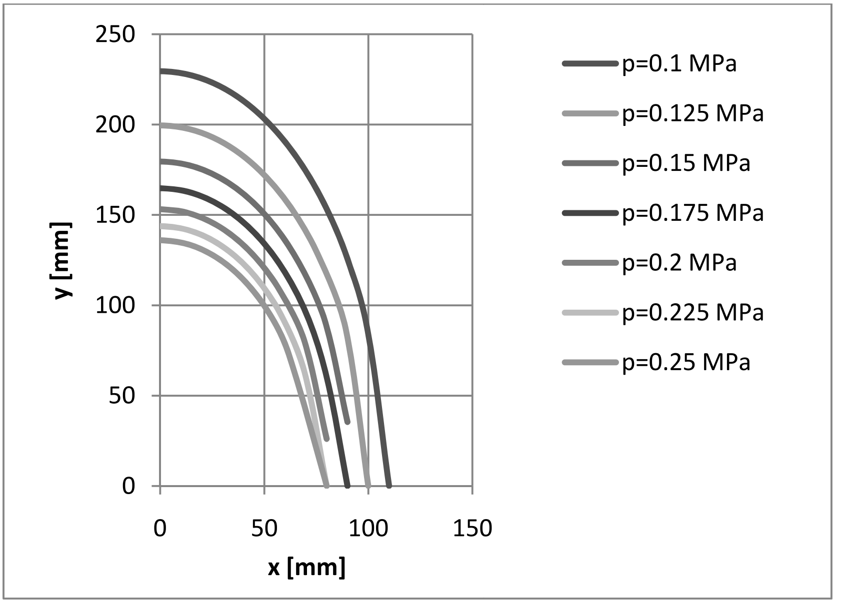

Fig. 11 Effect of inflation pressure on the contact area

CONCLUSIONS

1. Equations (22), (26), respectively (30) can be used for the calculus of the contact length, contact width, and contact area of the tires on rigid surfaces.
2. Experiments led to the conclusion that equations (22), (26), respectively (30) allow to estimate the details of contact geometry under varying load, inflation pressure and tire geometry parameters.
3. From figure 9 it is found that equation (30) used in the calculus of theoretical area of contact track A_2 is even more sensitive and closer to the real value of the surface of contact track A_3 when inflation pressure is higher. For lower values of inflation pressure it was found a contiguity of the theoretical results for the calculus of surfaces A_1 and A_2.

ACKNOWLEDGEMENT

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 629.3.015.5:631.372
Prethodno priopćenje
Preliminary communication

PRELIMINARY TESTING OF TRACTOR TIRE VIBRATION CHARACTERISTICS ON NEW TEST FACILITY

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SUMMARY

Dynamic behavior of vehicles without elastic wheel suspension system, such as e.g. agricultural tractors, is strongly influenced by the properties of tires, which can exhibit complex behavior. It is therefore important to carry out investigations of tractor tire behavior, in order to increase ability to optimize performance characteristics of the vehicle or the tire itself. This further requires availability of appropriate test facilities and test methods. In this paper preliminary investigations of tractor tire vibration properties on new developed test facility is described. Linearized vibration parameters of investigated tire are determined by using drop-test method. Results of these investigations will be used to define procedure for more comprehensive tire testing. Sources of measuring deviations are identified and measures proposed for reduction of their influence in future investigations.

Key words: *tractor tire, vibration behavior, vibration investigations*

INTRODUCTION

Dynamic behavior – and therefore factors as e.g. vehicle stability or operator comfort – of vehicles without elastic wheel suspension system, such as e.g. agricultural tractors, is strongly influenced by the properties of tires. These itself can exhibit very complex behavior. Furthermore, contemporary tractor tires have to comply with requirements connected with ever higher speeds reached by these vehicles on public roads. This is contradictory to primary goal according to which they were designed, which is their behavior and properties on agricultural terrain. This contradiction calls for more comprehensive investigations of tractor tire behavior, in order to increase ability to optimize performance characteristics of the vehicle or the tire itself. This further requires availability of appropriate test facilities and test methods. In this paper preliminary investigations of tractor tire vibration properties on new developed test facility will be described. One of the goals of this research is to identify linearized vibration parameters of investigated tire by using drop-test method. This investigation represents an initial phase of designing investigation procedure for more comprehensive study of tire dynamic behavior. Second goal is to get acquainted with facility properties and practical issues of its use. It should be revealed if further design changes and improvements are needed in order to carry out further investigations.

TIRE VIBRATION PROPERTIES

Vertical load from the vehicle is transmitted from the wheel to the tire, which generates ground reaction force and tire deflection. Total force by which tire withstands deformation arises from several physical mechanisms [7]:

I. Force from sidewall deformation
II. Additional sidewall stiffening due to tire pressure
III. Air compression inside the tube
IV. Air pressure force

Total force represents a sum of individual components. Figure 1 shows general look of influence of individual components as function of tire deflection. Components I and II cause both elasticity and damping, due to rubber viscoelasticity and internal friction of carcass material. Components III and IV are above all source of elasticity, since internal friction of the air is negligible compared to this of rubber.

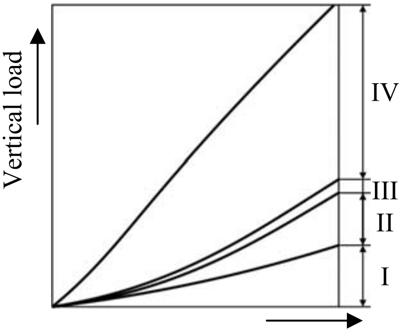

Figure 1 Structure of the tire load carrying ability (components explained above) [7]

Due to the factors like complex geometry, composite structure, large deformation, rubber viscoelasticity etc. tractor tires often exhibit very complex forms of behavior. A number of models which describe this behavior are known in the literature. These models are based on different modeling approaches and show different degrees of complexity. One of the most simple and still most frequent used models is model of linear vibrations with viscous damping, Figure 2. This model does not aim to reflect real nature of tire dynamics, but can give reasonably good approximation under appropriate circumstances. This applies above all in the cases when excitation frequency is relatively low, i.e. when spatial wavelength is much bigger than tire contact length so that the exact geometry of deformation does not play an important role. Because of this fact and its simplicity, this model is very widely used.

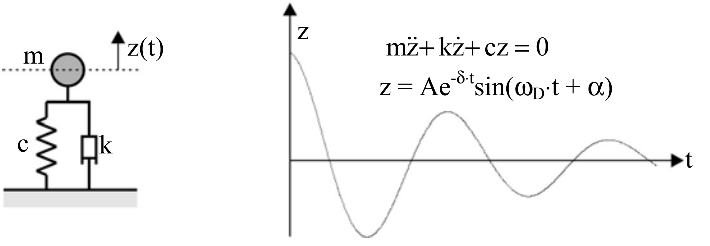

Figure 2 Vibration system with viscous damping: c – spring stiffness, k – damping coefficient, m – vibrating mass, z – position of the mass m

TIRE LINEARIZED VIBRATION PARAMETERS DETERMINATION PROCEDURE

As known from vibration theory, motion of the system shown in Fig. 2 is described by relation:

$$z = Ae^{-\delta \cdot t}\sin(\omega_D \cdot t + \alpha) \tag{1}$$

where:

$$\delta = \frac{k}{2\,m} \tag{2}$$

ω_D – damped natural frequency.

Period of free vibration with damping T_D can be determined according to vibration chart as time distance between two successive amplitude peaks. Relation between T_D and ω_D is given by expression:

$$T_D = \frac{2\,\pi}{\omega_D} \tag{3}$$

Knowing value for T_D, it is now possible to determine value of δ by using logarithmic decrement:

$$\ln\frac{z_i}{z_{i+1}} = \delta \cdot T_D \;\;\Rightarrow\;\; \delta = \frac{1}{T_D} \cdot \ln\frac{z_i}{z_{i+1}} \tag{4}$$

z_i and z_{i+1} – successive amplitude peak values, determined from vibration chart.

Using values for T_D and δ natural frequency of the system without damping ω_0 can be obtained. According to (3) and since it applies:

$$\omega_D = \sqrt{\omega_0^2 - \delta^2} \tag{5}$$

Follows:

$$\omega_0 = \sqrt{\left(\frac{2\pi}{T_D}\right)^2 + \delta^2} \tag{6}$$

Knowing mass m, and taking into account relation for undamped natural frequency:

$$\omega_0 = \sqrt{\frac{c}{m}}$$

it is now possible to determine stiffness c:

$$\boxed{c = m\omega_0^2 \text{ – linearized tire stiffness}}$$

After δ has been determined, damping can be calculated according to (2):

$$\boxed{k = 2m\delta \text{ - linearized tire damping}}$$

Fraction of critical damping is often used as indicator of the system vibration properties:

$$\boxed{D = \frac{k}{2\sqrt{cm}} \text{ - fraction of critical damping}}$$

More comprehensive treatment of given explanations can be found in any book covering basic vibration theory, e.g. [6].

INVESTIGATION PROCEDURE

Investigation of tractor tire vibrating behavior has been carried out using test facility shown in simplified manner in Figure 3. Facility consists of the cart guided on the rails, in which vertically movable frame is mounted. Tractor tire with its shaft connects to this frame. Tire rolls on the horizontal ground, at which different shapes of profile can be attached in order to excitate tire vertical motion. Test facility is described in detail in [5].

Basic tire vibrating behavior was investigated using drop-test method. This is done by letting rolling tire to fall off the platform of the height h=10cm as shown in Figure 3. Initial vertical velocity in the moment of touching the ground excitates tire to vibrate in vertical direction. Vertical tire displacement in time is being measured by appropriate transducer. Acquired data are stored on the PC for later processing and analysis.

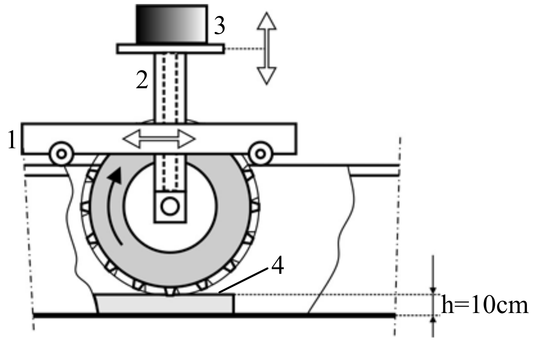

Figure 3. Schematic view of the test facility: 1 – cart, 2 – vertically movable carrying frame, 3 – load, 4 – elevated platform

On the basis of investigation results it is possible to determine values of linearized vibration parameters by using logarithmic decrement method described above. As tire rolls, vertical motion due to lugged tread, together with potential deviation of ground flatness or/and tire roundness, can interfere with vibrational movements caused by tire elasticity. This can aggravate data analysis and interpretation. In order to minimize these unwanted influences, tire was pushed over the platform edge without initial speed in horizontal direction. This way a lowest possible speed of rolling is achieved, i.e. minimal interference possible under given conditions. Each measuring is conducted three times, in order to get insight into repeatability and presence and level of noise in measured signal.

Because of significant influence tire pressure exerts on vibration parameters, investigations have been carried out for several different pressure values. These values are determined in accordance with earlier investigations of other authors [1], [3], [4]. Levels of vertical load for investigations are determined taking into account tire load capacity data from different manufacturers for given tire dimensions. More comprehensive description of the procedure for pressure and load choices is given in [2]. Review of chosen values is given in Table 1.

Table 1 Chosen values of influential parameters

Tire pressure, p [bar]	0.5	Vertical load, G [daN]	760
	0.8		
	1.2		1210
	1.5		

Investigations have been conducted with the tire of size 12.4 R 28, of radial construction.

RESULTS AND DISCUSSION

Measuring results for used combinations of pressure and load are shown in Chart 1 (for 760 kg load) and Chart 2 (1210 kg).

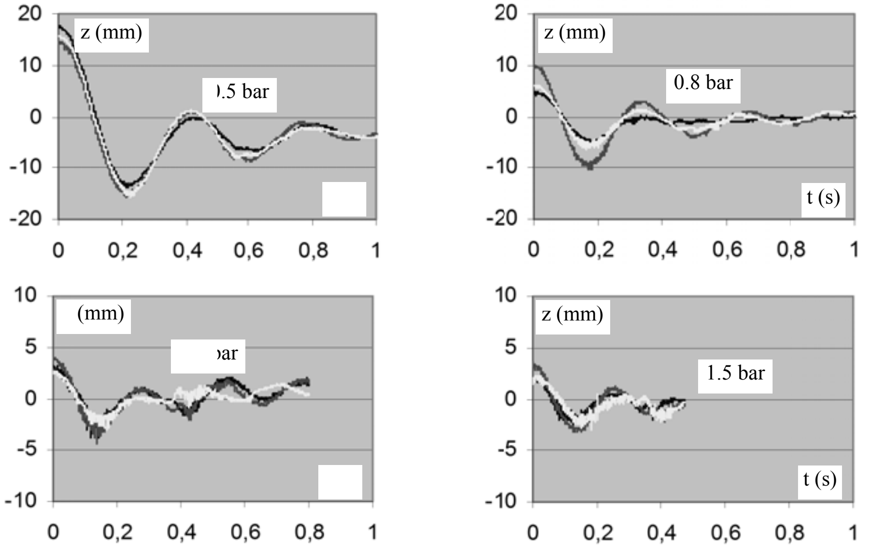

Chart 1 Graphical representation of tire vibration properties investigation by using drop-test method, at vertical load of 760 kg

Charts show that there is agreement of tire behavior with chosen vibrational model, although not quite completely. Approximately exponential decay of amplitude is noticeable, as well as influence of stiffness (i.e. tire pressure) and vibrating mass change on period of free vibration with damping. On the other hand, in some cases there is significant dissipation of results, and even deviation from assumed model. In the case of 1210 kg load and 0.5 bar pressure sidewall deflection is very pronounced, so that front part of contact surface comes in contact with the ground while rear part of it is still on the elevated platform. In that case motion was quite different from assumption. Further, there are deviations in initial amplitude in cases of 760 kg – 0.8 bar and 1210 kg – 1.5 bar can be explained by variation in lug position at the moment of leaving the platform. Position of lugs determines altitude of system center of mass, which determines initial speed at the moment of tire/ground contact establishing. This further influences maximum value of amplitude at the beginning of vibration process. This fact, though, should not influence obtained results, since system vibration parameters do not depend on initial conditions. Still one of the curves obtained by 1210 kg – 1.5 bar exhibits shape that does not enable conduction of described method. In some cases nature of deviation is such that after 1 or 2 oscillations curve regularity is more or less loss. This deviation aspect is most pronounced in cases of 760 kg – 1.2 bar and 1.5 bar. This is most probably result of superposition with the motion due to tire roll as described earlier, since in these cases period of vibration is the shortest. This leads to interference of other tire motions with vibrations caused by elasticity.

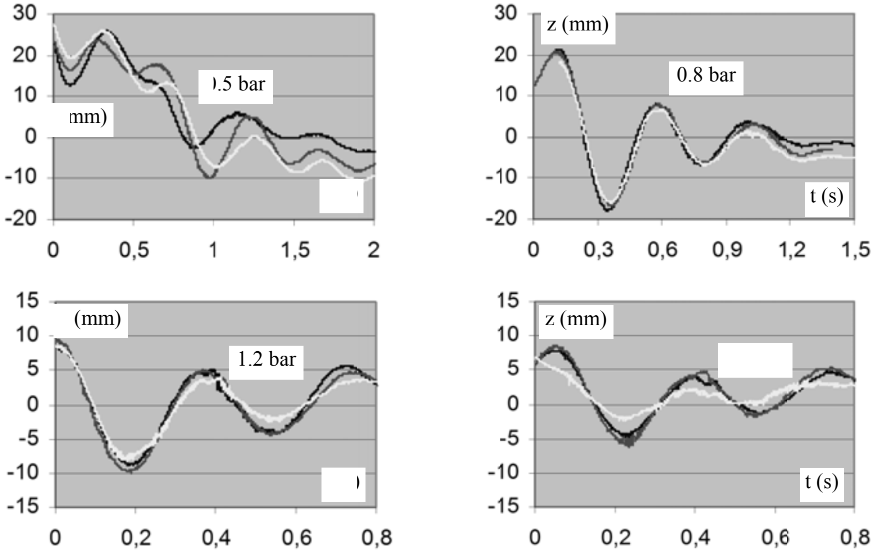

Chart 2 Graphical representation of tire vibration properties investigation by using drop-test method, at vertical load of 1210 kg

In order to keep unwanted influences on the lowest possible level, graphic determination of values needed for calculations has been conducted only for those parts of the charts which exhibited regular shape of free linear vibration with damping shown in Figure 2. Procedure of vibration parameter determination has been carried out for all cases except for 1210 kg - 0.5 bar, for the reasons already explained. Since in each cases three measurements are conducted, mean value and standard deviation for vibration parameters are determined. Results are shown in Tables 2 and 3.

Table 2 Statistic indicators for stiffness and damping coefficient

Pressure	Stiffness c		Damping coeff. k	
	Mean value	St. deviation	Mean value	St. deviation
0.5 bar	167.2 kN/m	7.9 kN/m	2.5 kNs/m	0.45 kNs/m
0.8 bar	235.6 kN/m	25.1 kN/m	2.3 kNs/m	0.41 kNs/m
1.2 bar	358.8 kN/m	30.0 kN/m	2.5 kNs/m	0.92 kNs/m
1.5 bar	442.7 kN/m	46.4 kN/m	2.7 kNs/m	0.60 kNs/m

Table 3 Statistic indicators for fraction of critical damping

Pressure	Fraction of critical damping m=760kg		Fraction of critical damping m=1210kg	
	Mean value	St. deviation	Mean value	St. deviation
0.5 bar	0.11	0.02	-	-
0.8 bar	0.08	0.02	0.07	0.001
1.2 bar	0.09	0.02	0.04	0.01
1.5 bar	0.07	0.03	0.06	0.002

Results obtained for the stiffness are in accordance with results of similar research published by other authors [1], [4], [8]. Clear trend of stiffness rise with tire pressure is found. Results for damping coefficient show expected trend of decrease with pressure rise, though not quite clear and unambiguous. Literature data shows that there can be pronounced variation in the magnitude of damping for different tires, so that comparison with published results was not made for this parameter. Similar can be also told for fraction of critical damping, whose magnitude though depends from vibrating mass as well. On Figure 4 prediction of model is compared to measurements for the case 1210 kg – 1.2 bar. Chart shows that adopted model can give reasonably good approximation of tire vibration properties if accuracy expectations are not set too high. Otherwise more complex modeling approach would have to be used.

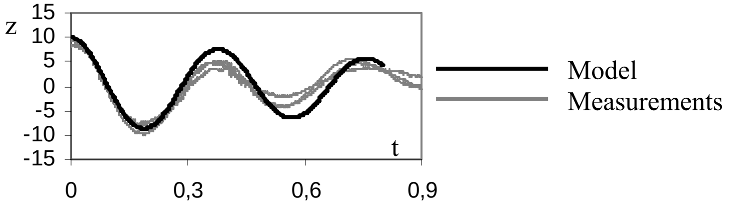

Figure 4 Model prediction compared to measurement results

CONCLUSIONS

Procedure has been described and results shown for investigations of vibration properties of tire 12.4R28 by using drop/test method. It is shown that tire vibrational behavior can be described by the model of linear vibration with damping. Due to deviations observed, in the case of higher expectations more advanced modeling approach would have to be used. Results obtained for tire vibration parameters are in accordance with expectations and with earlier investigations.

In time records of vibrating tire displacements it was observed that curve shapes contain parts different from vibrations caused by tire elasticity. One of most important sources of deviations presence of tire lugs can be named. Since there is no possibility to control lug angular position, this influence can be considered to be of random character.

It is ascertained that possible sources of systematic deviations can be: deviation of the roundness of the shaft, wheel and tire; eccentrically mounted wheel on the shaft; deviation of ground flatness etc. Therefore it is necessary to check and measure these values in order to be able to identify their influence on the measured values.

As next research step, obtained linearized parameters will be used, together with other relevant factors, for definition of excitating frequency spectrums i.e. appropriate shape of the ground profile. This will enable investigations of tire behavior in more complex conditions. Goals of planned future investigations are not only to acquire qualitative information about tractor tire behavior under different conditions, but also investigations of the basics for modeling approach development that is capable of more comprehensive and accurate description of vertical tire dynamics.

ACKNOWLEDGMENT

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.51
Stručni rad
Expert paper

THE EFFECT OF LONG TERM ALTERNATIVE SOIL TILAGE ON HORIZONTAL SOIL RESISTANCE

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SUMMARY

On a heavy soil of the parcel 'Center' the alternative soil tillage with CP has being applied for five years, whereby one half of the parcel is still under MP. The measurements of horizontal resistance were performed with a horizontal penetrometer designed at the Agricultural institute of Slovenia, which sampled data at 50 Hz during driving on the field, so on the average 4476 points were taken. From each part of the parcel data were collected from 15, 25 and 35 cm layer depth on 375 m long experimental parcel. The results of horizontal penetrometer showed on the average lower resistance in MP15 (40.98 Ncm^{-2}) than in CP15 (45.10 Ncm^{-2}) and in MP25 (91.66 Ncm^{-2}) than in CP25 (122.47 Ncm^{-2}). In the 35 cm depth the soil resistance was higher in MP (123.65 Ncm^{-2}) than in CP (115.99 Ncm^{-2}) probably because of the hardpan.

***Key words**: horizontal penetrometer, soil resistance, soil tillage, chisel, mouldboard plough*

INTRODUCTION

Alternative soil tillage with chisel plough (CP) can significantly reduce the fuel consumption in comparison with mouldboard ploughing (MP). However, long term abundance of MP might affect the horizontal soil resistance. In modern agriculture, the risk of soil compaction increases with the growth of farm operations and the drive for greater productivity causing by using heavier machinery. Excessive soil compaction has negative effects on soil structure, reduces crop production, increases runoff and erosion, accelerates potential pollution of surface water by organic waste and applied agrochemicals, and causes inefficient use of water and nutrients due to slow drainage (Johnson and Bailey, 2002).

According to Gill and Van den Berg (1968) soil compaction is the process in which the soil particles are rearranged to decrease empty space and bring them into closer contact with one another, thereby increasing the bulk density. The major contributor to forming soil compaction is various loads applied to the surface of unsaturated soils.

Quantitative evaluation of soil compaction is necessary to determine its severity and to identify suitable mechanical, chemical, or biological methods of intervention for ameliorating or controlling soil compaction. Two different methods are commonly used for measuring soil penetration resistance. In the first method, soil samples are taken over the field at a certain depth of soil with the help of an open-ended pipe and then the samples are analyzed in the laboratory to determine dry bulk density, dry specific volume, void ratio, and porosity (Culley, 1993). In the second method, a specifically sized conical tip is immersed into the ground vertically or horizontally to measure soil strength at a standard speed of 30 mm/s (Jones and Kunze, 2004). Soil strength has been widely used to estimate the degree of soil compaction. By nature, soil strength sensors are of *soil failure-type*. As this type of sensor is moved through the soil, it registers resistance forces arising from cutting, breakage and displacement of soil.

Contrary to the vertical penetrometer, which enables only point measurements of the soil strength, horizontal penetrometer can make instantaneous measurements during driving. The result of the measurement is a signal obtained at a certain distance, which was defined prior the experiment. On such way a higher quality data is possible to evaluate, because the impact of soil inhomogeneity is reduced, due to large amount of obtained measurements as it is in the case in the vertical penetrometer (Jejčič and Poje, 1996).

The main aim of this research was to determine whether alternative soil tillage with chisel plough (CP) can significantly reduce the horizontal resistance of the soil in comparison with mouldboard ploughing (MP) after being applied for five years on a heavy clay soil.

METHODS

Experimental site

For our investigation a field entitled 'Center' (Lat. N 15º40´36´´ Long E 46º35´58´´) with alternative and conventional soil tillage was selected. The silty clay loam contains 42 % of clay, 39 % of silt and 19 % of sand and can be characterized as a Gleyic Podzoluvisol.

In October one half of the field was ploughed at 28 cm depth and 140 cm width with a five body mouldboard plough, then a six meter width combination of rotary harrow and a pneumatic seeder was applied for sawing of winter wheat. On the other half of the parcel six meter width chisel was applied at 12 cm depth followed by a combination described earlier. The owner of the parcel has been using conservative tillage with the chisel for the last five-years.

MATERIAL

For measuring soil resistance a horizontal penetrometer was used, which is represented in Figure 1. The conical tip of the horizontal penetrometer was made of steel. The load cell bed was formed into the steel tine. The load cell was placed in this section and the top was covered. This prevents possible damage to the load cells under the soil. The data cables of the load cells were transported to the data collection unit, which was placed on the nearby driving vehicle, by being passed through the metal tubes placed behind the penetrometer's tip.

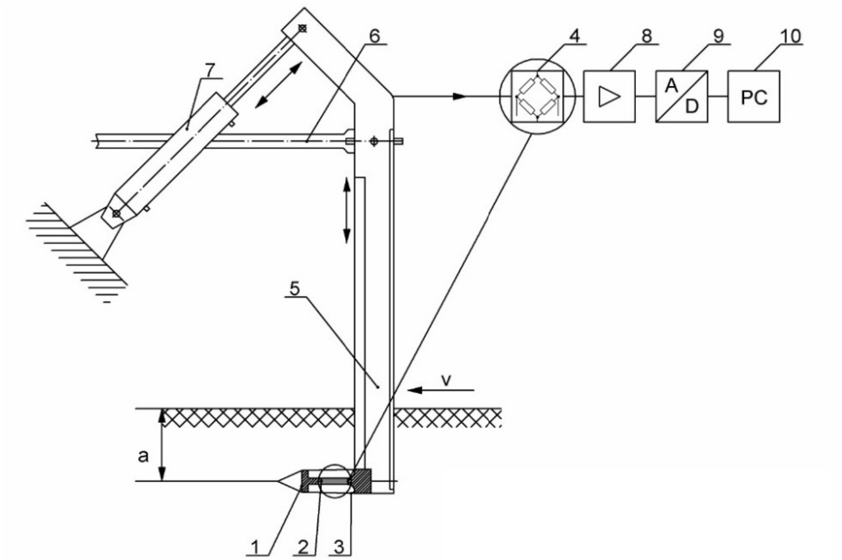

Figure 1 Horizontal penetrometer: 1 – conical tip, 2 – sensor of compressive force, 3 – protective armor, 4 – strain gauges, 5 - medium, 6 - tractor drawbar, 7 - hydraulic cylinder for adjusting tilt, 8 - magnifying glass, 9 - A/D converter, 10 – personal computer (Jejčič and Poje 1996)

Figure 2 Horizontal penetrometer during measuring on the field

Afterwards, a conical-shaped tip of 30° was placed into the hole, and fixed to the load cell. The surface of the designed conical-shaped tip is 18,086 cm^2. Insulation seals were used in order to prevent probable leakage of water or soil particles into the holes on the body. An adjustable wheel system was placed behind the penetrometer to ensure a well-maintained depth adjustment and proper running of the machine. By changing the inclination of knife holder of penetrometer and by releasing the hydraulic tractor drawbar we achieve that the penetrometer is buried below the topsoil at the proper depth and guided by a horizontal plane (Jejčič and Poje 1996).

RESULTS

Average horizontal soil resistance

All measurements of the horizontal resistance on the ploughed part of field is represented in Figure 3. Statistics may be seen in Table 1., which show the highest average horizontal soil resistance in the depth of 35 cm (124.77 N/cm^2) and the lowest in the depth of 15 cm (40.98 N/cm^2). In the deepest layer the maximum soil resistance (184.36 N/cm^2) was also detected, but it did not differ significantly from the maximum point in the 25 cm layer. On the other hand, in the 15 cm layer the values remains minimal during all the measurements.

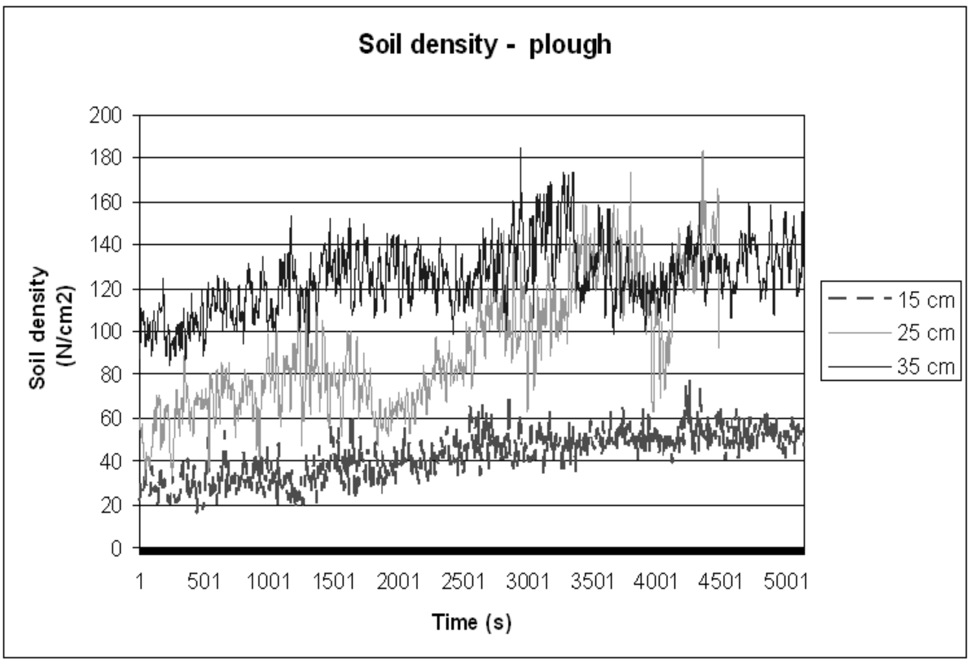

Figure 3 Horizontal soil resistance in three soil layers on the ploughed field

Table 1 Average horizontal soil resistance at plough

Depth (cm)	Average (N/cm²)	Standard deviation (N/cm²)	Maximum (N/cm²)	Minimum (N/cm²)
15	40.98 [a]	10.76	77.00 [a]	16.26 [a]
25	91.67 [b]	29.10	183.28 [b]	31.45 [b]
35	124.77 [b]	15.66	184.36 [b]	84.59 [c]

[a, b] statistically significant difference at $p < 0,05$

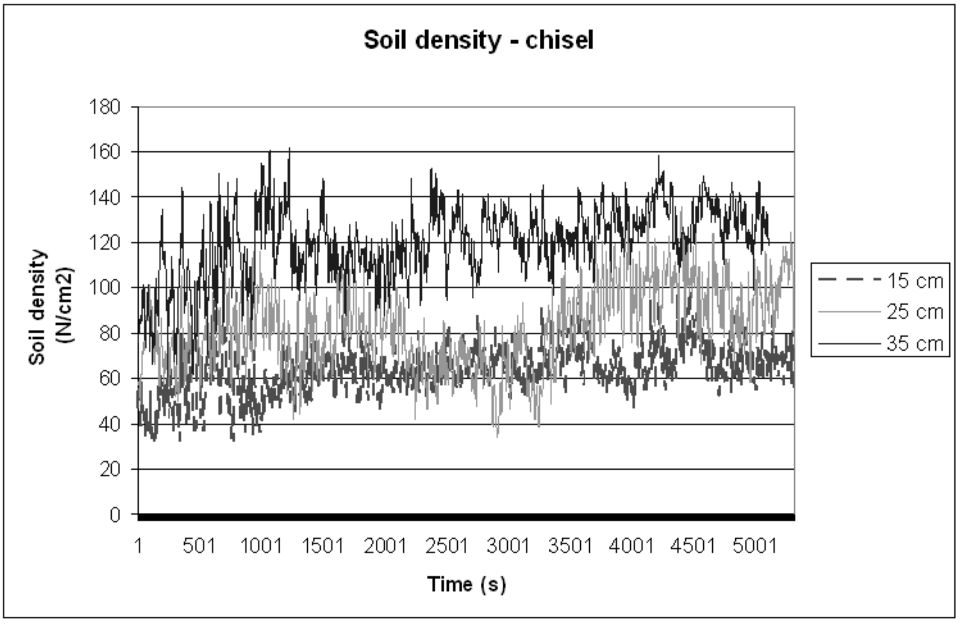

Figure 4 Horizontal soil resistance in three soil layers on the chiseled field

Table 2 Average horizontal soil resistance at chisel

Depth (cm)	Average (N/cm²)	Standard deviation (N/cm²)	Maximum (N/cm²)	Minimum (N/cm²)
15	62.57 [a]	11.01	98.69 [a]	31.45 [a]
25	91.67 [b]	29.10	135.56 [b]	33.62 [a]
35	120.05 [b]	15.97	161.59 [b]	60.73 [b]

[a, b] statistically significant difference at $p < 0.05$

Figure 4. represents all measurements of the horizontal resistance on the chiseled part of field. In the Table 2. statistics are shown. Again the highest average horizontal soil resistance of R_h= 120.05 N/cm² was measured in the deepest layer of 35 cm, while the

lowest resistance of R_h= 62.57 N/cm² was in the layer of 15 cm. In the deepest layer the maximum soil resistance of R_h= 161.59 N/cm² was measured, but it did not differ significantly from the maximum point in the 25 cm layer. The minimum values remained during all the measurements in the 15 cm layer.

CONCLUSIONS

Alternative soil tillage with chisel plough was proved in some previous experiments (Stajnko et al., 2009) to significantly reduce the fuel consumption in comparison with mouldboard ploughing on the heavy silty clay loam soil. The result of measurements showed that using of alternative tillage with chisel for five years increased the average soil resistance for 21.09 N/cm² in the top 15 cm soil layer in comparison with mouldboard ploughing. Contrary, in 25 cm and 35 cm layer no significant difference in the average horizontal resistance was found between chisel and plough.

ACKNOWLEDGEMENTS

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UTJECAJ VIŠEGODIŠNJE PRIMJENE SUSTAVA ALTERNATIVNE OBRADE NA HORIZONTALNI OTPOR TLA

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SAŽETAK

*Alternativna obrada tla s chisel plugom (CP) može značajno smanjiti potrošnju goriva u usporedbi s oranjem (MP). Međutim, dugoročno izostavljanje MP može utjecati na horizontalni otpor tla. Na teškim tlima parcele 'Centar' alternativna obrada tla s CP primjenjuje se već pet godina, pri čemu je polovica parcele još uvijek u MP. Mjerenja horizontalnih otpora su izvedena horizontalnim penetrometrom dizajniranim na Poljoprivrednom institutu Slovenije, koji skuplja podatke kod 50 Hz za vrijeme rada na terenu, tako da su u prosjeku skupljene 4476 točke otpora tla. Sa 375 m dugačkog eksperimentalnog poligona skupljeni su podaci sa 15, 25 i 35 cm dubine sloja tla. Rezultati horizontalnog penetrometra pokazali su u prosjeku niži otpor u sloju MP15 (40,98 Ncm^{-2}) u odnosu na CP15 (45,10 Ncm^{-2}) i u sloju MP25 (91,66 Ncm^{-2}) u odnosu na CP25 (122,47 Ncm^{-2}). U 35 cm dubine otpor tla bio je veći u MP (123,65 Ncm^{-2}) u odnosu na CP (115,99 Ncm^{-2}) najvjerojatnije zbog nepropusnog sloja (*hardpan*) na nekim mjestima.*

***Ključne riječi**: horizontalni penetrometar, otpor tla, obrada tla, chisel, plug*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.51:662.75:621.182.3
Prethodno priopćenje
Preliminary communication

MOBILE LABORATORY FOR THE EVALUATION OF THE POWER INDICES OF THE AGRICULTURAL UNITS

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SUMMARY

In order to evaluate the power indices (traction force, fuel consumption and wheel slip) of the agricultural units, especially for the tractor mounted and semi mounted implements (plows, chisels, tillers etc.), a mobile testing laboratory was designed and carried out. The test laboratory uses a 2WD U-650 tractor (with a four cylinders, 65 HP diesel engine) provided with the following equipments: a dynamometric frame, a device for measuring the fuel consumption and a device for measuring the number of turns of each driving wheel.

The dynamometric frame is hinged to the tractor chassis by the means of a deformable parallelogram type of mechanism, provided with a hydraulic three-point hitch. A strain gauge load cell makes the connection between the dynamometric frame and the tractor chassis, along its longitudinal axis, allowing the measurement of the traction force.

Two fuel meters (CONTOIL, VZO-4RE, one impulse for each 1.25 ml of fuel consumption) were used in order to measure the fuel consumption; one was placed on the fuel supply line and the second was paced on the fuel return line. A TRUEMETER 9201 digital counter, with six digital inputs, was used in order to count the number of pulses from each fuel meter, the difference between the two readings providing the fuel consumption.

In order to measure the wheels slip, a gear with ten teeth was mounted on each wheel axle; two induction proximity sensors (SAGATC, IMN4-M12E0) were used in order to obtain ten impulses for each complete turn of the driving wheels. The same TRUEMETER 9201 digital counter was used in order to read the number of turns of the driving wheels.

Key words: *soil tillage, wheel slip, traction resistance, fuel consumption*

INTRODUCTION

The testing of the tractor mounted or semi-mounted agricultural equipment implies the evaluation of the power indices: real driving speed, traction power and force, wheels slip and hourly fuel consumption[4, 8, 9]. Different types of devices are used in order to measure these indices; some of them use the mechanical principle, while others convert the mechanical parameters into electrical parameters, which are measured by the means of a mobile laboratory, equipped accordingly [1, 2, 3,]. The second type of devices allows a more accurate measurement of the power indices[5, 6, 7].

MATERIAL AND METHOD

At the Agricultural Machinery Department of the University of Agricultural Sciences Iaşi a mobile laboratory was developed, based on the Romanian U650 tractor. The tractor was equipped with the devices needed in order to measure the traction force, the slip of the driving wheels, the hourly fuel consumption and the duration of the test.

The device for measuring the traction force

While for the trailed agricultural equipment the measuring of the traction force is achieved by the means of a force transducer, mounted between the equipment and the tractor, for the mounted and semi-mounted agricultural machinery this principle can not be used, as these use the three-point hitch mechanism of the tractor.

In order to measure the traction force for the rear-attached implements, a dynamometric frame was developed, as shown in fig. 1.

The dynamometric frame (2), provided with a hydraulic three-point hitch mechanism (6), is hinged to the tractor chassis by the means of four vertical rods (3). Thus, the dynamometric frame is allowed to move along the tractor's longitudinal axis. The implement (14) is carried by the three-point hitch mechanism (6).

The dynamometric frame is connected to the tractor chassis by the means of a 2500 daN load cell (4). An electronic controller (10) is used to display the average value of the traction force.

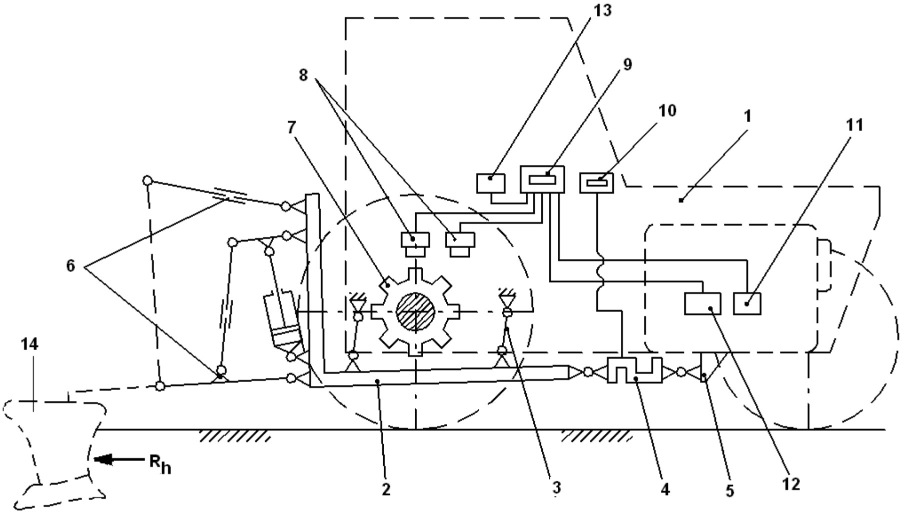
The device for measuring the fuel consumption

Two turbine type flowmeters were used in order to measure the fuel consumption. The main features of the flowmeters are as follows:

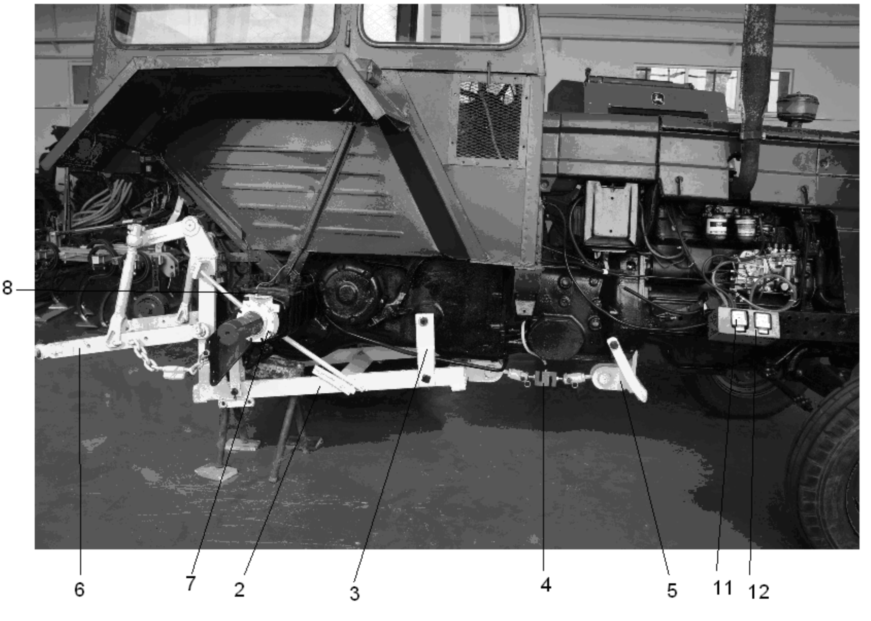
- type: VZO 4, produced by AQUAMETRO AG Switzerland;
- pipe diameter: 4 mm;
- maximum working pressure: 4 bar;
- minimum flow: 1 l/h;
- maximum flow: 80 l/h.

The flowmeters provide one impulse for each 1.25 ml of fuel flowing through.

In order to evaluate the fuel consumption two flowmeters were used: one was placed on the fuel supply line (Ct_1, fig. 2) and the second one on the fuel return line (Ct_2).



a)



b)

Fig.1 Mobile laboratory for the evaluation of the power indices
a – schematics; b – general view;
1 – tractor; 2 – rigid frame; 3 – hinged vertical rods; 4 – load cell; 5-rigid jack on the tractor chassis; 6- hydraulic three-point hitch mechanism; 7-toothed disc, mounted on the wheel drive shaft; 8-inductive sensor; 9-digital counter with six inputs; 10-force measuring controller; 11-flow meter on the fuel line; 12-flow meter on the fuel return line; 13-electronic pulses generator; 14-tractor mounted implement

The hourly fuel consumption was calculated with the formula:

$$Q_h = \frac{1{,}25 \cdot 10^{-3} \cdot (n_1 - n_2) \cdot 3600}{\tau \cdot \rho} \quad \left[\frac{kg}{h}\right],$$

where n_1 and n_2 is the number of impulses given by the corresponding flowmeter, τ is the duration of test, in seconds, and ρ is the fuel density, in kg/m^3.

The device for measuring the wheel slip

Drive wheel slip was evaluated with the formula:

$$p = \left(1 - \frac{n_g}{n_s}\right)^2 \cdot 100 \quad [\%],$$

where n_g is the average number of turns of the drive wheels in order to travel a certain distance with no equipment mounted on the tractor and n_s is the average number of turns of the drive wheels in order to travel the same distance with the implement mounted on the tractor and in operating position.

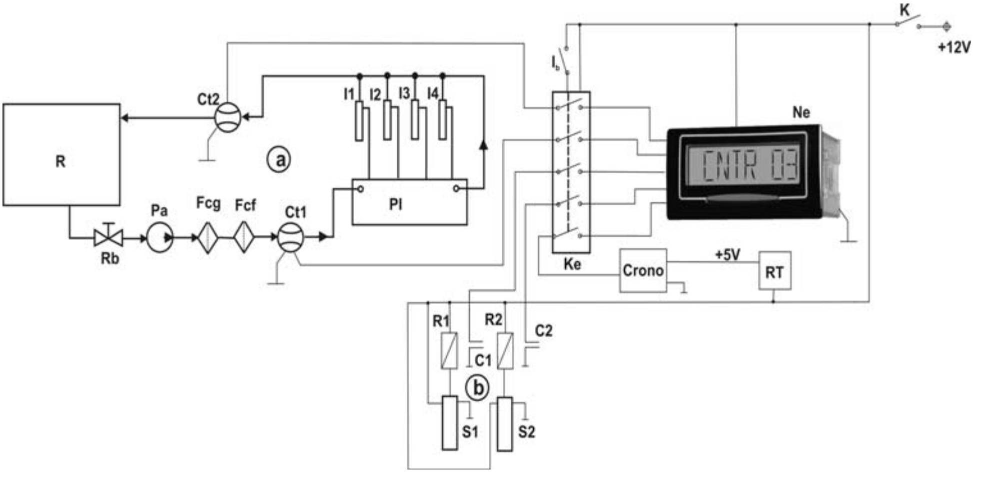


Fig. 2 Schematics of the fuel consumption, drive wheels slip and time measuring devices a-fuel consumption measuring device; b-drive wheels slip measuring device; R-fuel tank; Rb-valve; Pa-fueling pump; Fcg, Fcf-fuel filters; Ct_1, Ct_2-flow meters; PI-fuel injection pump; I_1, I_2, I_3, I_4-fuel injectors; S_1,S_2-inductive proximity sensors; R_1, R_2-relays; C_1, C_2-normaly open electric contacts; Crono-10 Hz impulses generator; RT-voltage regulator; Ne-digital counter; Ke-electronic switch; Ib- tilting switch; K-key switch

The number of turns was computed as the arithmetic mean value between the left and right wheel:

$$n_s = \frac{n_{s \cdot dr} + n_{s \cdot \cdot stg}}{2}; \quad n_g = \frac{n_{g \cdot dr} + n_{g \cdot stg}}{2} \quad ,$$

where the subscript ***g*** refers to the no equipment situation, the subscript ***s*** refers to the operating position of the agricultural implement, the subscript ***dr*** refers to the right wheel and the subscript ***stg*** refers to the left wheel.

In order to measure the number of turns a toothed disc with 10 teeth (7, fig. 1) was mounted on the drive shaft of each wheel; inductive proximity sensors, type IMN4-12EO (SAGATC Technologies – 8, fig. 1), were used in order to provide ten impulses for each complete turn of a drive wheel. Figure 2 shows that the proximity sensors S_1 and S_2 are connected to the relays R_1, R_2 and the normally open contacts of the relays (C_1 and C_2) provide the electric impulses needed by the digital counter Ne.

The time measuring device

In order to calculate the real speed of the tractor and the hourly fuel consumption the duration of the test must be known. In order to achieve this goal a 10 Hz electronic pulses generator was used. The impulses generator is based on a 5 MHz quartz crystal oscillator; the frequency was then divided by 5.10^5 in order to obtain the 10 Hz signal; thus, time can be evaluated with a precision of 0.1 s. The 10 Hz signal is applied to the digital counter (Ne, fig. 2).

The digital counter

In order to display the measured parameters (wheels slip, fuel consumption, duration of the test) a digital counter (type 9201, Trumeter, England) is used. The counter has six digital inputs, of which only five are used and displayed. The counter has a built in RS 232 interface allowing a PC to be used to configure/ communicate with the unit.

In order to simultaneously start and stop the counting of the different electric signals, the connection with the digital counter was achieved through an electronic switch (Ke, fig. 2), which is using bilateral CMOS transmission gates (74HC4016 integrated circuits). A high level on the control terminal of each gate enables the transmission of the signal from its input to its output, while a low-level signal on the control terminal isolates the output from the input. All the control terminals are switched simultaneously by the means of the tilting switch (Ib, fig. 2).

The values stored by each of the count inputs of the digital counter are displayed one by one when repeatedly pressing the front panel button (2, fig. 3). When the control button is pressed for more then 5 seconds, the content of the corresponding counter is cleared.

In order to evaluate the power indices of the agricultural unit, the mobile laboratory is displaced on a distance of 100 m, marked by two poles; the tilting switch (Ib, fig. 2) is switched on when passing by the first pole and then is switched off, when passing by the second pole.

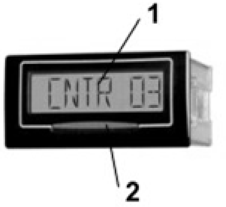


Fig. 3 The 9201 Trumeter digital counter; 1-display, 2-front panel button

The traction force is displayed by the electronic controller (10, fig. 1) and must be written down by the operator during the test

RESULTS AND DISCUSSIONS

In order to test the mobile laboratory a P-2VA type variable width mouldboard plough was mounted on the three-point hitch mechanism of the dynamometric frame. The working speed was bellow 3 km/h, the working depth was 25 cm and the drive wheels slip was under the required limit of 20%.

During the tests the working speed, the traction resistance, the drive wheels slip and the hourly fuel consumption were evaluated.

The tests were performed in different conditions regarding the type of soil and its humidity, texture and apparent density, as presented in Table 1.

Table 1 Testing conditions

Working conditions	**Test site**			
	1	**2**	**3**	**4**
Field slope, degrees	0	2	3 - 4	0
Type of soil	alluvial	cambic chernozem	cambic chernozem	salty wet meadow
Clay content, %	29	31	34	62
Soil texture	loamy	loamy	clay loam	heavy clay
Soil structure	crumbly	crumbly	micro crumbly	micro crumbly with clods
Apparent soil density, g/cm^3	1,52	1,58	1,50 – 1,54	1,46 – 1,48
Soil humidity, %	22,0	19,4	13,2 – 20,4	23,2 – 28,0
Precursory crop	autumn barley	maize	maize	maize

As far as the soil type was concerned, it is obvious that the conditions were different: alluvial soil, cambic chernozem, salty wet meadow soil.

Soil texture varied from loamy, with 20-31% clay, to heavy clay, with 62% clay. The soil structure was various, with particles of different sizes.

The apparent soil density was comprised between 1.46 g/cm^3 to 1.58 g/cm^3, thus exceeding the recommended values: under 1.4 g/cm^3 for the loam soil, under 1.3 g/cm^3 for the clay loam soil and under 1.2 g/cm^3 for the clay soil.

For all the types of soil (except for the clay loam soil), the humidity exceeded the optimum values, which are as follows: 9-16% for the loamy soil, 12-19% for the clay loam soil and 16-22% for the clay soil.

The results of the tests performed over the P-2VA plow, mounted on the mobile laboratory, are shown in Table 2.

Table 2 Power indices for the U-650 + P-2VA agricultural unit

Clay content %	**Soil humidity** %	**Apparent soil density** g/cm^3	**Working speed** km/h	**Hourly fuel consumption** kg/h	**Drive wheels slip,** %	**Traction resistance** N	**Specific plowing resistance** N/cm^2
29	22,0	1,52	3,20	9,600	15,0	10423	6,29
31	19,4	1,58	3,32	8,860	11,2	10250	7,48
34	13,2	1,54	3,00	7,780	18,3	12784	7,20
	16,5	1,51	3,26	7,300	16,5	10860	6,78
	20,4	1,50	3,33	8,430	15,6	10800	6,70
62	23,2	1,46	3,51	9,420	10,8	11024	8,32
	28,0	1,48	3,54	9,280	11,0	9620	8,63

During the tests the U-650 tractor was driven in the first gear, corresponding to a theoretical speed of 3.83 km/h. The real working speed of the agricultural unit was comprised between 3.00 and 3.54 km/h. The results show that several factors affected the working speed (the soil's clay content, humidity and apparent density, the traction resistance and wheels slip), but it was difficult to emphasize the effect of each item. Nevertheless, it was noted that the highest working speed (3.54 km/h) was achieved for the lowest traction resistance of the plow (9260 N), the maximum humidity (28.0 %) and for low values of the apparent density (1.48 g/cm^3) and wheels slip (11.0%). The lowest working speed (3.00 km/h) was registered in the following conditions: highest traction resistance (12784 N), maximum wheels slip (18.3%), lowest humidity (13.2%) and high apparent density (1.54 g/cm^3).

The hourly fuel consumption was comprised between 7.300 kg/h and 9.600 kg/h. The lowest fuel consumption was recorded for 17.5% soil humidity (the optimum value being 12...19% for the clay loam soil). The highest recorded value of the fuel consumption (9.600 kg/h) was due to the higher apparent density of soil and to the fact that humidity exceeded the prescribed limits (9...16% for the loam soil). High values of the fuel consumption

(9.420 kg/h and 9.280 kg/h) were also recorded for soils with a high clay content (62%) and a humidity exceeding the optimum value (16...22% for clay soils).

The traction power of the P-2VA plow was evaluated based on the fuel consumption and on the full load characteristic of the D-110 Diesel engine (mounted on the U-650 tractor). The experimental results showed that, depending upon the working conditions, the traction power required by the plow was comprised between 35 and 57 HP; these values are lower than the 65 HP full load power of the D-110 type engine. As a result, it was established that, at the maximum fuel consumption regime, 87.7% of the engine's power was used during plowing; this value is within the required limits of 80…95%.

Drive wheels slip did not exceed the maximum acceptable limit of 20% (for compacted terrains). For the clay soil, when a traction resistance of 9620 N was recorded, wheel slip achieved the minimum value of 11.0%; the maximum slip was achieved for the maximum traction resistance of 12784 N.

The traction resistance for the P-2VA plow recorded values comprised between 9620 and 12784 N.

The specific resistance of soil was comprised between 6.29 N/cm^2 and 8.63 N/cm^2; the lowest value was recorded for the medium soil, with a loam texture and a clay content of 29%. The highest values (8.32 N/cm^2 and 8.63 N/cm^2), were recorded for the heavy, clay soil, having a clay content of 62%. The peak value of the specific resistance (8.63 N/cm^2) is due both to the high clay content and to the exceeding of the optimum humidity (16...22% for the clay soil).

CONCLUSIONS

- The preliminary tests showed that all the devices of the mobile laboratory perform according to the design requirements.
- The tests performed with the U-650 tractor + P-2VA plow agricultural unit proved that high values of the clay content and soil apparent density led to higher values of the specific traction resistance.
- The soil's specific traction resistance increased when the optimum value of the humidity for the corresponding soil texture was exceeded.
- The lowest fuel consumption was recorded when soil humidity was within the recommended limits. Higher fuel consumptions were recorded for higher values of soil humidity, apparent density and clay content.
- At the maximum fuel consumption regime, 87.7% of the engine's power was used during plowing; this value is within the required limits of 80…95%.
- Wheels slip did not exceed the maximum recommended value. A lower slip was recorded for the low values of the traction resistance and clay content, while the maximum slip was recorded when the traction resistance was at its peak.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631. 42/.43
Stručni rad
Expert paper

LABORATORY TEST RIG FOR STUDYING THE INTERACTION BETWEEN THE ACTIVE PARTS OF THE AGRICULTURAL UNITS AND SOIL

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SUMMARY

The interaction between the active parts of the agricultural units and soil, as well as the interaction between the wheels of the units and soil is a complex process, which is difficult to evaluate in real conditions and which affects the fuel consumption for the tillage operations, as well as the preservation of the soil. In order to study this process a laboratory test rig (soil channel) was designed and carried out.

The rig is provided with a bin, filled with soil with the dimensions of the aggregates comprised between 0.02 and 50 mm; the rig is also provided with a mobile carriage, which driven by a travel cable at a speed of 0.5…1.5 m/s. Different active parts or tire wheels can be mounted on the carriage in order to study their interaction with the soil.

The test rig allows the evaluation of the energy consumption and of the technological effect as a function of the working depth, soil compaction and working speed.

Using both the computer models and the experimental results soil compaction due to traffic may be evaluated, for different types of tires, for the following working regimes of the wheel: driving wheel, driven wheel, braking wheel.

Two strain gauge load cells allow the measurement of the traction force needed to displace the carriage.

The test rig achieved the following parameters: working depth of active part 0 ... 300 mm, speed of the carriage 0,5 ... 1,55 m/s (1,8 ... 5,58 km/h), maximum pull-down force 500 daN, maximum cable traction force 800 daN at 0,55 m/s and 280 daN at 1,55 m/s.

Key words*: laboratory test rig, active parts, tire wheel, soil interaction, soil bin*

INTRODUCTION

Physical degradation of the soil, caused by the interaction with the active parts and support wheels of the agricultural equipment, refers especially to structural deterioration and compaction [4, 8, 9, 10].

Experimental studies must be performed in order to evaluate the effect of tillage works and to establish the critical values leading the physical degradation of the soil because of the action of the active parts and wheels [1, 2, 3, 11].

Moreover, it is necessary to establish the correlation between the working parameters of the active parts and wheels, on one side, and the indices concerning soil structure and compaction, on the other side [5, 7, 8].

There may be about 150 soil bins in use around the world, with only several new soil bins built since 1983 [6]. This was the reason why a laboratory test rig was designed and constructed at University of Agricultural Sciences and Veterinary Medicine from Iasi, aiming to perform studies referring to the interaction between soil and the active parts and wheels of the agricultural equipment. The similarity laws were considered in the designing process the test rig, in order to reproduce, in laboratory conditions, the complex working processes occurring at the contact surface between the working parts and soil and between the wheels of agricultural units and soil. The studies performed using the test rig allowed the evaluation of the working parameters of the active parts and wheels (traction resistance force, wheel slip etc.) and the impact over the physical and mechanical properties of the soil.

MATERIALS AND METHODS

The test rig (fig. 1) consists of a rigid frame (1), the soil bin (2), the carriage (3), on which the active part (plough body) for soil tillage (6), the tire wheel (7) and the leveling & settling drum (8) are mounted; a winch is fixed at the end of laboratory test rig, allowing the movement of carriage by the means of a cable (5).

The winch is composed of an electric motor (9), a cylindrical gear (10) and a drum (11); the drum drives the cable (5), thus towing the carriage (3). The ends of the traction cable are attached to the carriage frame through the load cells (4), thus allowing the measurement of the traction forces needed to the drag carriage.

In order to drive the tire wheel (7), the carriage is fitted with an electric motor (12) and a reduction gear. The working depth of the active body can be adjusted by the means of the screw mechanism (13). The screw mechanism (14) is used in order to adjust the vertical position of the tire wheel, while the screw mechanism (15) is used in order to change the vertical position of the soil leveling and compaction drum.

A control panel (18) is used for the power supply of the two electric motors; the electric cables are guided by the means of a steel cable (16), fixed on the pillars (17).

Due to its length (10240 mm), the soil bin is composed from five sections, joined together by screws. At the inside, the bin is coated with a plastic sheet.

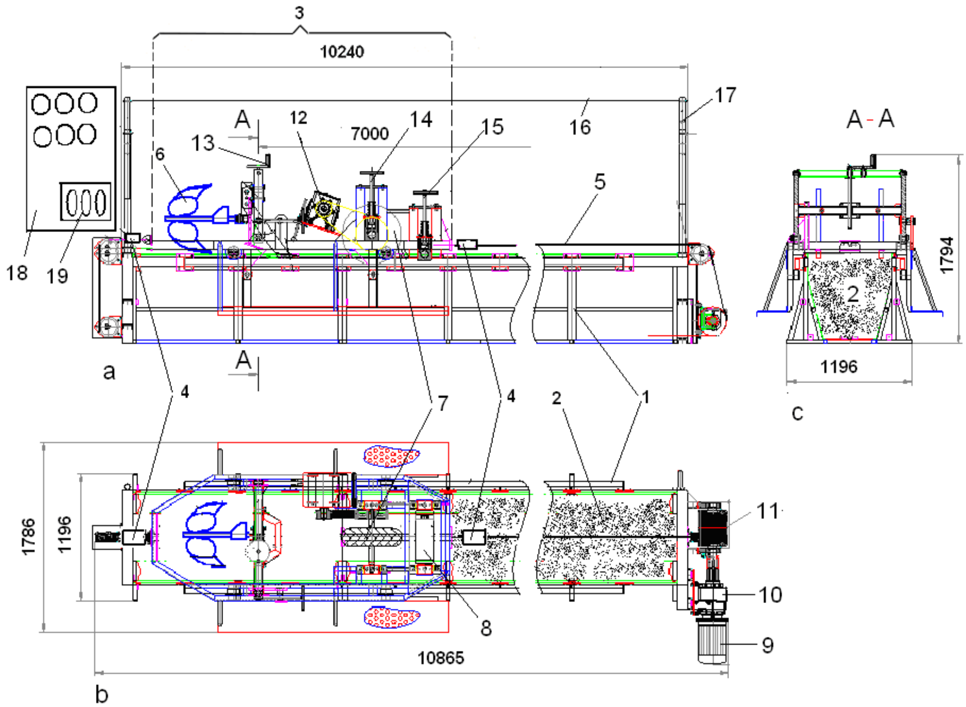

Fig.1 Laboratory test rig with soil channel for the study of the interaction between the active parts or agricultural wheels and the soil

The soil leveling and compaction roller (8), mounted on the carriage, is used in order to achieve different compaction levels of the soil, before processing it with the active body or performing various experiments with tire wheel.

Four upper trundles – two in the front and two in the back – and four lower trundles - also two in the front and two in the back - are mounted on the carriage frame; the trundles are rolling on rails, mounted on each side of the frame of the soil channel.

When the carriage is towed by the means of the cable, the tire wheel (7) rotates due to its interaction with the soil and thus the conditions corresponding to a driven wheel are simulated. When the carriage is not towed, the wheel (7) becomes a driving one, being driven by the electrical motor (12) by the means of a cylindrical gear drive and of a belt drive. Thus, the conditions corresponding to a driving wheel are simulated.

The towing cable is connected to the carriage through two strain gauge load cells, allowing the measurement of the traction force needed to move the carriage.

The electric control panel is used in order to feed the test rig. The electrical motors are controlled by the means of a frequency converter, allowing the adjustment of the rotation speed when the frequency is modified between 3 and 50 Hz. The dynamic braking principle is used in order to stop the carriage at the end of its stroke. Switches on the control panel allow the selection of the feeded electric motor (the carriage towing motor or the tire wheel driving motor), as well as its forward or reverse motion.

The force transducers measure the thrust; they provide a voltage signal when the steel carriage is moved back and forth, which is measured and displayed. The two load cells have a measuring limit of 1000 daN and are fitted with spherical joints at both ends; they are connected to a programmable weighing controller, which displays the mean values of the corresponding sampling signal, eliminating the dynamic loads that occur due to the vibrations produced by the electric stand and soil unevenness. Thus, a true and readable value is displayed

The laboratory test rig has the following features: tire wheel: 5,00 – 12,4 PR (width = 127 mm, outside diameter = 569 mm), with antiskid V profiles; the electric motor used to tow the cable trolley: 5,5 kW at 1000 rot/min; the electric motor used to drive the tire wheel: 3 kW at 1000 rot/min; trolley race: 7 m; type of traction cable (tow trolley): D8 6x19 Seale IWR ISO 2408 (cable diameter = 8 mm, the cable made up of six strands, each strand with 19 wires); internal dimensions of the soil channel: 0,8x0,8x10 m (width x height x length); overall dimensions of the laboratory test rig (Lxlxh): 2035x10865x1764 mm; transmission ratio of the cylindrical gear (tow trolley): 24,31; transmission ratio of cylindrical gear driving the tire wheel: 28,76; total transmission ratio from the engine to the tire wheel movement: 57.

A bill chernozen type of soil was used to fill the soil bin, with loam-clay texture, the aggregate size of 0.02 ... 50 mm and 17-19% humidity.

RESULTS AND DISCUSSION

Evaluation of the test rig working parameters

In the first phase, the rig was tested in order to evaluate if the desired parameters are obtained. It was found that the test rig has the following constructive-functional parameters: working depth of the active implement: 0 ... 300 mm; adjustment of working angle of the active part relative to the soil surface: (-) 25^0 ... (+) 25^0; the speed of the carriage when towed by the 5,5 kW electric motor: 0,5 ... 1,55 m/s (1,8 ... 5,58 km/h); the maximum pull-down force for the with tire wheel and the soil leveling and settlement drum: 500 daN; maximum traction force of the cable (of the carriage), at a speed of the trolley of 0,55 m/s: 800 daN; maximum traction force of the cable (of the carriage) at a speed of the carriage of 1,55 m/s: 280 daN; cable breakdown point: 40,83 kN. It was concluded that there were no significant differences between the design parameters and the achieved ones.

Experiments with the plough body mounted on the laboratory test rig

In the second phase, the laboratory test rig was used in order to study the soil-moldboard plough body interaction and the tire wheel-soil interaction (fig.2).

When the moldboard plough body was tested, the influence of working depth, soil resistance to penetration and travel speed on the traction resistance and specific power consumption were evaluated. The results of the tests are presented in Table 1.

It should be noted that the test rig reproduces, in laboratory conditions, the working process of a moldboard plow body. The working width of the plow body was 200 mm. The plowing unit mounted on the test rig was equipped only with the basic elements: share and moldboard.

The experimental results presented in the Table 1 show that increasing the speed of the plough body results in the increase of the traction resistance. In the meantime, when the speed plough body increases, the specific power consumption significantly increases.

As expected, increasing the soil's resistance to penetration resulted in a sharp increase of the traction resistance and an important increase of the specific power consumption.

As far as the third factor of influence (working depth) is concerned, it was found that increasing of the penetration depth of the plough body resulted in a marked increase of the traction resistance.

It was noted that increasing the working depth of the plough body resulted in an uneven change of the specific power consumption: increasing the working depth from 100 mm to 150 mm caused a slight decrease of the specific power consumption; when further

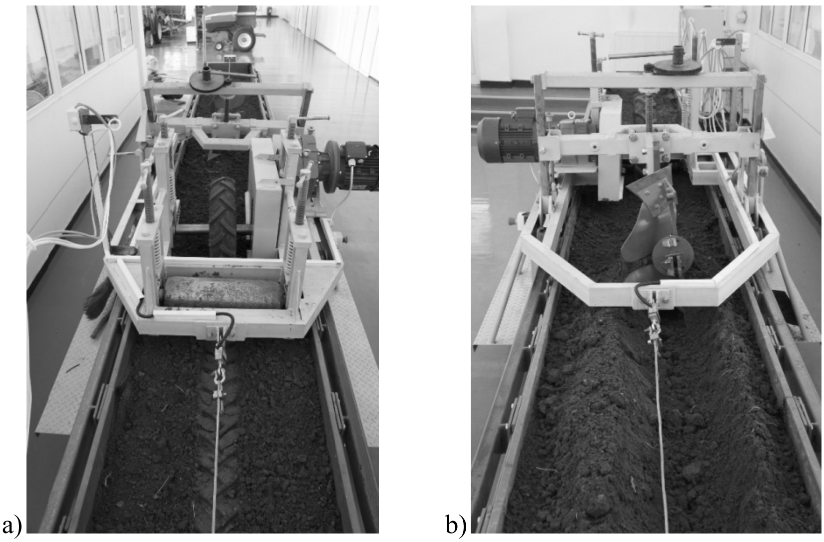

Fig. 2 Laboratory experiments in order to study of the interaction of tire wheel and active part with the soil: *a* – study of the wheel -soil interaction; *b* – study of the plough body - soil interaction

It was noted that increasing the working depth of the plough body resulted in an uneven change of the specific power consumption: increasing the working depth from 100 mm to 150 mm caused a slight decrease of the specific power consumption; when further increasing the working depth from 150 mm to 200 mm, the specific power increases. These variations in the specific power were explained as follows: for low working depths (below 15 cm) the soil slice was not deployed as furrow and was not overturned, so that the specific power was low; for depths over 15 cm, there were better conditions to overturn the furrow, so that supplementary power was needed to complete this action.

Table 1 Operating parameters of the laboratory test rig by modeling the interaction of plough body –soil

Working depth of plough body (mm)	Soil resistance to penetration (MPa)	Speed of plough body (m/s)	Traction force (N)	Specific power (W/cm^2)
100	0,2	0,75	705	2,65
		1,00	720	3,60
		1,25	735	4,59
	0,4	0,75	925	3,47
		1,00	940	4,70
		1,25	960	6,00
150	0,2	0,75	1055	2,64
		1,00	1070	3,57
		1,25	1080	4,50
	0,4	0,75	1380	3,45
		1,00	1400	4,67
		1,25	1420	5,92
200	0,2	0,75	1450	2,72
		1,00	1470	3,67
		1,25	1485	4,64
	0,4	0,75	1859	3,47
		1,00	1890	4,72
		1,25	1930	6,03

In the series of experiments regarding the driving wheel mounted on the test rig, the tire wheel was used to drive the carriage along the soil bin; the wheel was driven by the 3 kW electric motor.

The test aimed to evaluate the main operating parameters of the driving wheel. The effect of the wheel speed, soil penetration resistance and wheel pushdown force over the carriage speed, wheel slip and wheel traction force was studied. The results obtained in these experiments are summarized in Table 2.

The results show that wheel slip decreases when its speed increases; in the meantime, the traction force decreases when the wheel's speed increases.

As far as the soil resistance to penetration is concerned, it was concluded that an increased penetration resistance led to the increase of the wheel speed, because a more compact soil increases the adherence of the driving wheel, and to the increase of the speed. An increased soil penetration resistance also increased the traction force, due to the same effect (better adherence of wheel).

Table 2 Evaluation of the test rig operating parameters with motored wheel

Wheel speed (rev/min)	Soil resistance to penetration (MPa)	Down force over the wheel (N)	Speed of the trolley (m/s)	Driving wheel slip (%)	Traction force of the driving wheel (N)
20	0,2	500	0,50	17	230
		750	0,51	15	360
		1000	0,53	14	580
	0,4	500	0,51	15	290
		750	0,52	15	442
		1000	0,54	13	610
30	0,2	500	0,75	16	220
		750	0,76	15	350
		1000	0,79	12	570
	0,4	500	0,76	15	285
		750	0,77	14	438
		1000	0,79	12	600
40	0,2	500	0,99	15	220
		750	1,01	14	340
		1000	1,02	11	560
	0,4	500	1,01	14	280
		750	1,01	13	410
		1000	1,04	10	580

Regarding the effect of the wheel down force, it was established that an increased force resulted in an increased wheel speed and, consequently, an increased speed of the carriage, due to diminished wheel slip. An increased down force led to a lower wheel slip, due to the higher wheel adherence; for the same reason, traction force increased when the wheel down force was increased.

CONCLUSIONS

Taking into account the measured values of the main operating parameters of the test rig, that resulted from the first series of experiments performed, no significant differences were recorded between them and those set by design.

Regarding the experimentation of the plough body mounted on the carriage of the laboratory test rig, it was established that an increased speed of the moldboard plough body led to the increase of traction force; in the meantime, an increased speed resulted in an increase of the specific power consumption. As far as the soil resistance to penetration was concerned, it was concluded that its increase led to a sharp increase of the traction force and specific power consumption.

In the experimental tests showed that increasing the working depth of the plough body depth resulted in significant increase of the traction force. In addition, increasing the working depth from 100 mm to 150 mm resulted in a slight decrease of the specific power; when the working depth further increased from 150 mm to 200 mm, the specific power increased.

In the experiments concerning tire wheel mounted on the carriage of laboratory test rig, operating in a motored regime, the results showed that increasing the wheel speed resulted in decreased wheel slip and traction force.

An increased soil resistance to penetration led to the increase of the wheel speed and traction force and to the decrease of the wheel slip.

An increased down force over the driving wheel led to the increase of the carriage speed and of the wheel traction force, while the wheel slip decreased.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631.331.52
Stručni rad
Expert paper

THE ESTABLISHING OF CORN WITH THE EQUIPMENT FOR SOIL TILLAGE AND SOWING IN NARROW STRIPS

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INMA Bucharest, Romania

SUMMARY

INMA Bucharest has designed, developed and tested an experimental model of equipment for soil preparation in narrow strips and sowing within the innovative technology for soil preparation and crops establishment appropriate to sustainable agriculture, adapted to climatic conditions specific to Romania regions. It enables multiple operations in a single pass. The paper presents the experimental investigations of technical equipment and preparation parameters of the aggregate with 103 kW tractor for the corn crop establishment and the aggregate with 110 kW tractor for determining the operating indicators. The results obtained from the experimental research allowed designing validation of the preparation bodies for the technical equipment proposed within the establishing technology for hoeing plants in sustainable system.

***Key words**: soil, strips, sowing, hoeing plants, fertilizing, insecticides*

INTRODUCTION

Continuous intensification of agriculture will increase negative effects on the environment through degradation of its various components: soil, atmosphere, surface and deep water [1]. It results the need of alternative for soil preparation and plant cultivation to minimize the depreciation of the soil and allow the performance of quality works on time and with minimum energy consumption, low production costs and high profits. One of these alternatives is sustainable agriculture which aims to enhance agricultural production by optimizing the use of agricultural resources and helping to reduce lands widespread degradation through integrated management of available soil, water and biological resources combined with external raw material.

Equipment presented in this paper is modular designed which enables soil preparation in an area called "narrow strip" in one passing. In the second passing chemical fertilizers and insecticides were applied. On that way the covering and light compaction are achieved in a single passage, which reduce significantly the soil compaction, energy consumption and labor cost.

MATERIALS AND METHOD

Two variants of innovative technology of soil preparation and hoeing crops setting appropriate to sustainable agriculture depending on soil and climate conditions, cultivated plant and fertilizing and pests control have been elaborated within INMA Bucharest (Fig. 1).

For performing the experimental researches in field conditions, in order to determine the working qualitative indicators and energy indicators, was used a NH T6070 tractor, as existing equipment within INMA Bucharest, which has the following main technical characteristics: overall dimensions (length × width × height), mm: 5347×2230×3040; tractor mass, kg: 10000; wheelbase, mm: 2734; track at the front / rear axle, mm: 2030/2030; engine power: 103 kW (140 HP) [5].

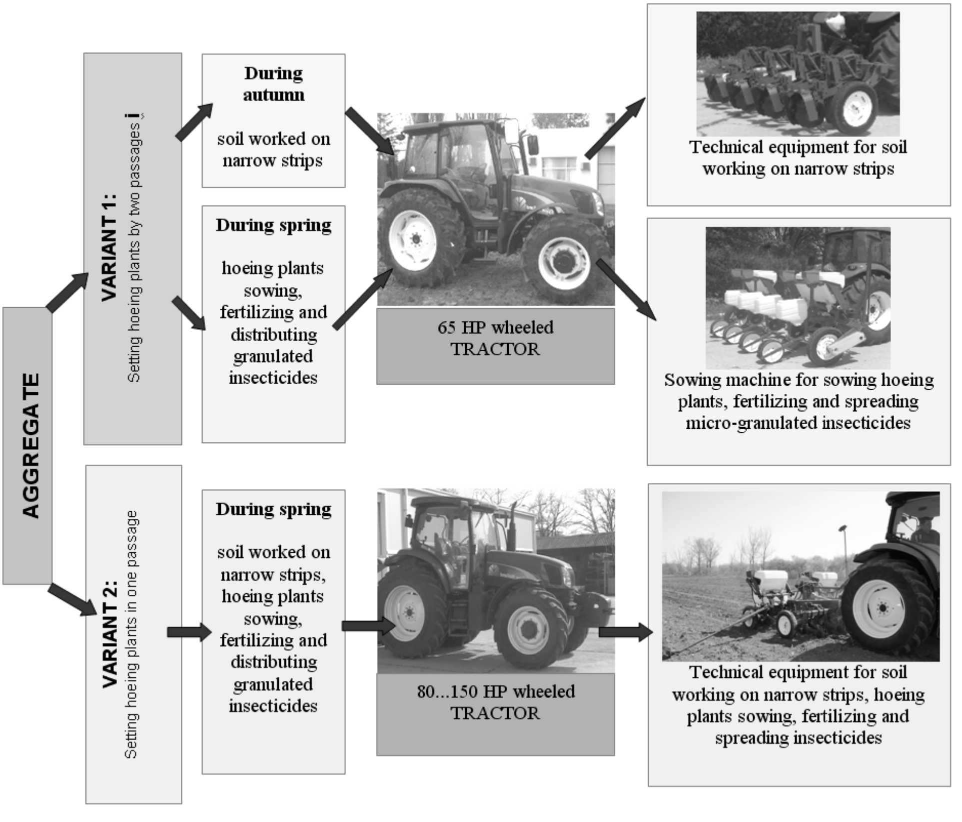
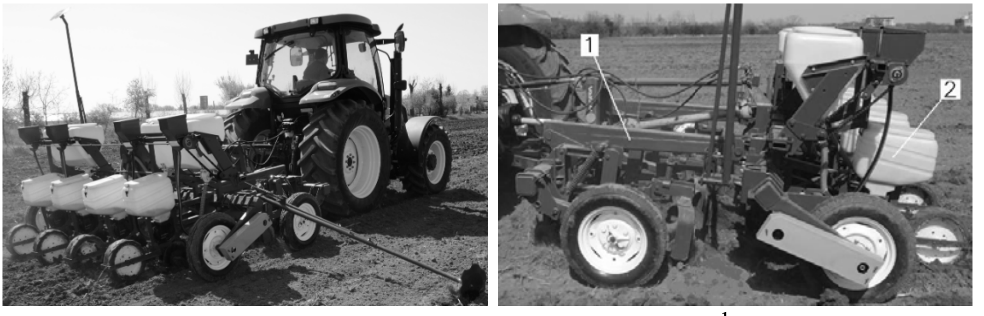


Fig. 1 Variants of innovative technology performed by INMA Bucharest

Technical equipment for soil preparation in narrow strips, sowing, fertilizing and distributing granular insecticides (Fig. 2a) consists of an equipment for soil preparation in narrow strips (Fig. 2b/1) and a plant seeder concomitantly with fertilization and distribution of granular insecticides (Fig. 2b/2).



a. b.

Fig. 2 Equipment for soil preparation in narrow strips, sowing, fertilizing and distributing granular insecticides (a - rear right side view, b - left side view)

The section for soil preparation in narrow strips (Fig. 3) consists of different assemblies: two notched discs mounted tilted (Fig. 3/1), the straight notched disc (Fig. 3/2), the knife with reversible chisel (Fig. 3/3) and two spherical notched discs (Fig. 3/4) behind it.

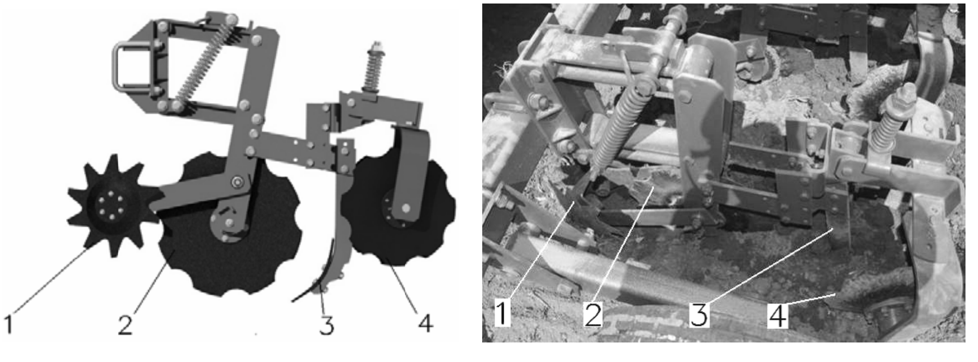


Fig. 3 Section for soil preparation in narrow strips

The constant maintaining of the working depth is performed using the two tension springs (Fig. 4/1) mounted on the deformable parallelogram and the compression spring (Fig. 4/2) mounted on the mounting bracket of the two spherical notched discs.

The sowing sections (Fig. 5) are mounted on the sowing machine frame bar (Fig. 2b) through a system of articulated bars and a plate fixed with two clamps. The constant maintaining of the working depth is performed using a tension spring (Fig. 5/5) mounted on the deformable parallelogram.

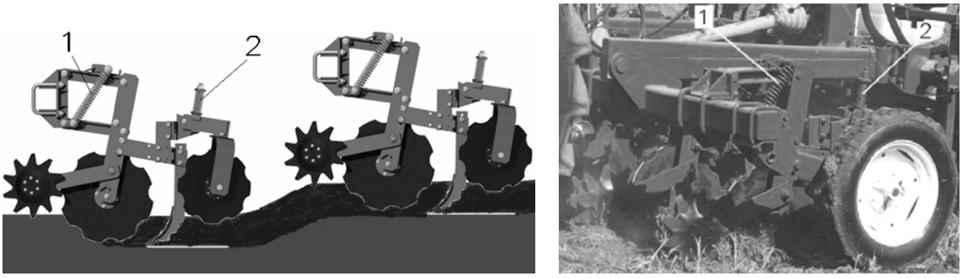


Fig. 4 The constant maintaining of the working depth

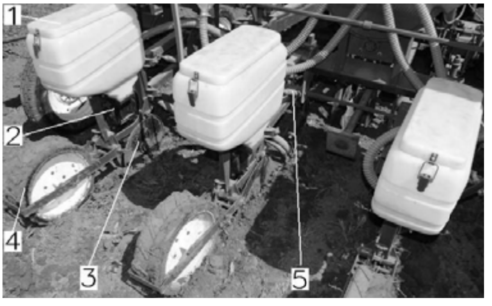


Fig. 5 Sowing section

The pneumatic planter is made of two housings between which are rotating the interchangeable sowing disc. Depending on the seeds variety, the holes of sowing discs have the diameter from 2.5 to 5.5 mm. The discs are easily changed without using any tool. In order to eliminate losses of seeds and vacuum between the vacuum chamber (Fig. 5/2) and the disc, a sealing gasket is provided.

Table 1 The main technical characteristics of the equipment used in the experiment

Characteristic	**UM**	**Value**
Number of section for soil preparation	pcs	4
Distance between the sections for soil preparation	mm	700
Number of sowing sections	pcs	4
Number of sowing coulters	pcs	4
Distance between the rows sown	cm	12.5
Sowing depth	cm	2...12
Working width	m	2.8
Mass	kg	1383

All equipment for soil preparation in narrow strips, plant seeder, fertilizer and distributer of granular insecticides are produced according to the patent application no. A1637 / 10.11.2009 [6].

The tests were performed on the experimental fields of INMA Bucharest in accordance with a specific procedure for testing and requirements of SR 13238 [8] and STAS ISO 7256/1-92 [9]. Additional equipment for determining the soil characteristics of the experimental field represents:

- Electronic digital cone penetrometer FIELDSCOUT SC 900
- Capacitive soil humidity measuring device FIELDSCOUT TDR 300
- Navigation device Garmin GPSMAP 60 CSx
- Mechanical timer
- Electronic balance METTLER PM 6000
- Portable scale RW10P
- Electronic tachometer
- Frame with strain gauge marks
- Amplification and data acquisition system MGC plus type.

The frame with strain gauge marks (Fig. 6) allows coupling of three-point linkages 3, 3N, 4, 4N category according to ISO 730:2009 [7] of the tractors and agricultural machines within respective categories.

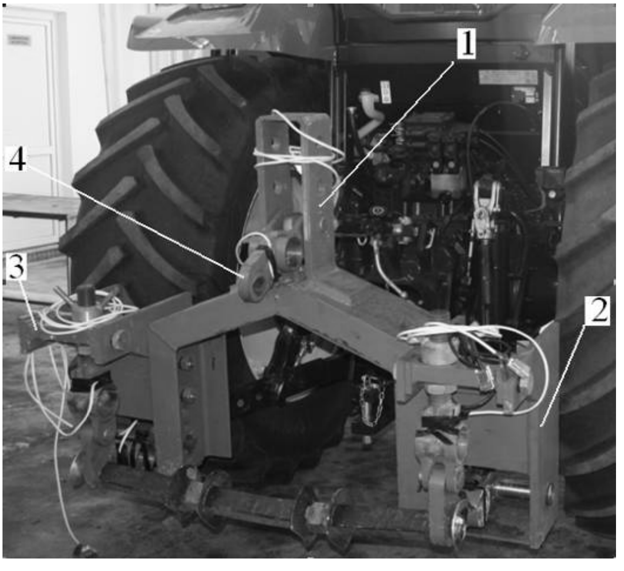


Fig. 6 The frame with strain gauge marks, coupled to three-point linkages 3 category according to ISO 730:2009 of the tractor

The following qualitative indicators were determined:

- The ploughing depth
- The working width
- The sowing depth

Determining of drawbar forces was performed via tensiometric [2] three point hitch dynamometer coupled with PC and software Catman that assures acquisition, processing and filtering raw data. The CATMAN software specialized in data acquiring and processing has allowed filtering the signals received from transducers and determining their minimum, average and maximum values.

The traction power P_{tr} was calculated on the basis of aggregate displacement speed v_l and traction force F_{tr} previously determined by means of relation [3], [4]:

$$P_{tr} = \frac{F_{tr} \times v_l}{3600}, \text{ kW} \tag{1}$$

where F_{tr} is measured in N and v_l in km/h.

RESULTS AND DISCUSSION

The following indices of qualitative work were determined with technical equipment in the aggregate with 103 kW (140 HP) tractor NH T6070. **The coefficient of variation of the working depth** was calculated according to the following equation:

$$cv_a = \frac{\sigma_a}{\overline{a_m}} \times 100, \% \tag{2}$$

where σ - standard deviation of working depth in cm, $\overline{a_m}$ - average working depth in cm and n- number of measurements.

The graphical representation of average working depth and variation index for three working speeds are shown in figure 7.

The working width coefficient of variation was calculated according to the next equation:

$$cv_B = \frac{\sigma_B}{\overline{B_m}} \times 100 \ \% \tag{3}$$

where σ - standard deviation of working width in cm work and measured at a point in cm, $\overline{B_m}$ - average working width in cm and *n* - number of measurements.

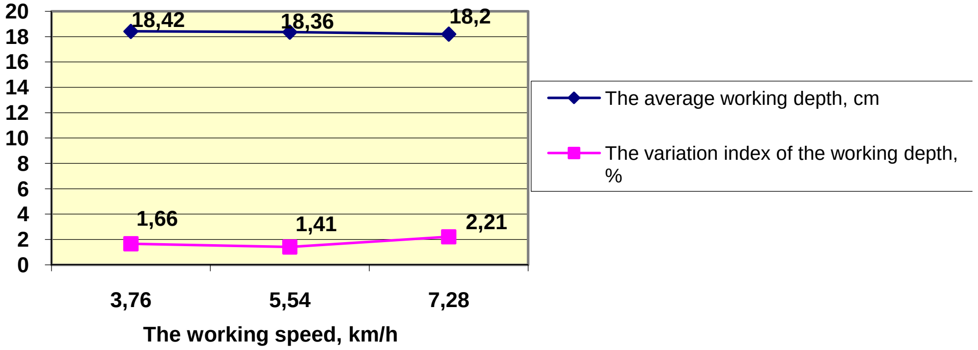


Fig. 7 Graphical representation of soil average working depth

Graphical representation of soil average working width and variation index for three working speeds are shown in figure 8.

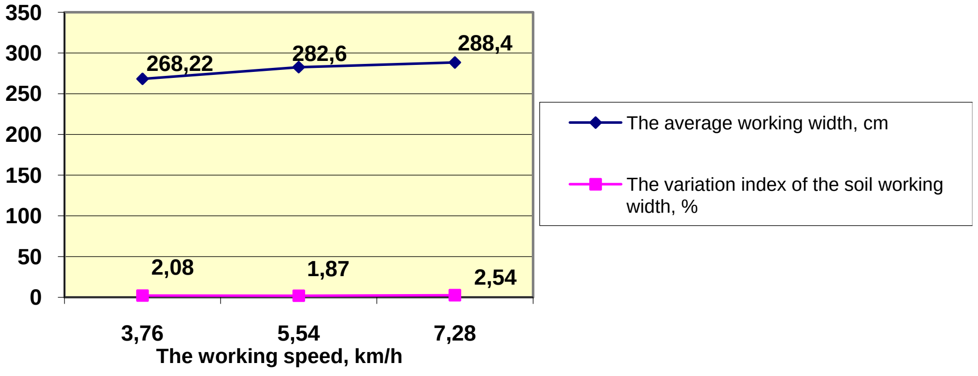


Fig. 8 Graphical representation of soil average working width

The variation coefficient of incorporating depth of seeds was calculated according to the following equation:

$$cv_a = \pm \frac{\sigma_a}{\overline{a_m}} \times 100\,\% \qquad (4)$$

where σ - standard deviation of sowing depth in mm, $\overline{a_m}$ average sowing depth in mm, and n- number of measurements.

The graphical representation of average corn sowing depth variation and variation coefficient of incorporating depth depending on working speed on row 1, 2, 3 and 4 are presented in figures 9, 10, 11 and 12.

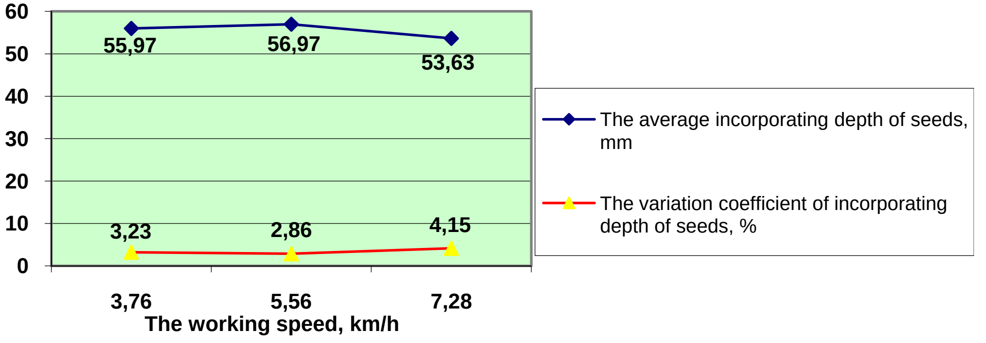


Fig. 9 Graphical representation of variation of average incorporating depth and variation coefficient according to working speed for row 1

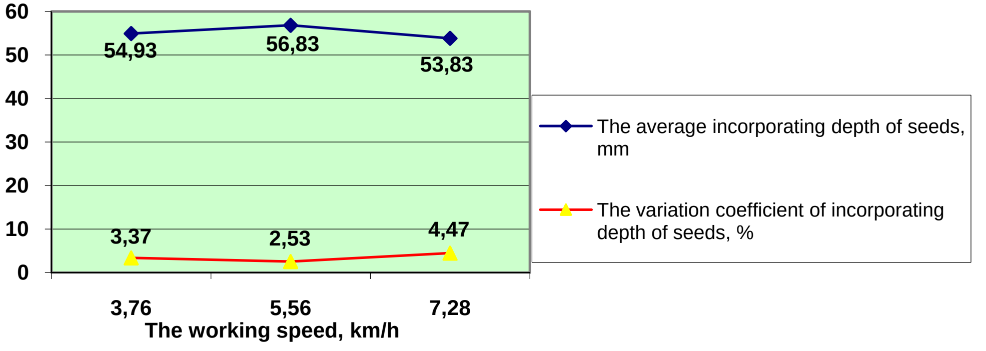


Fig. 10 Graphical representation of average depth and variation coefficient according to working speed on row 2

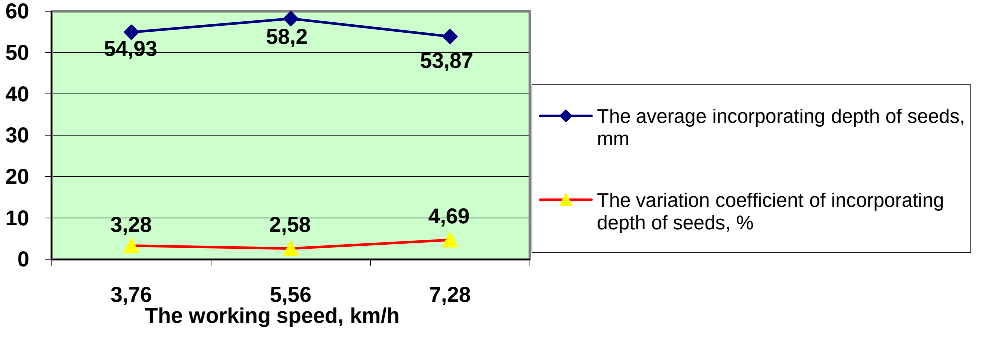


Fig. 11 Graphical representation of average depth and variation coefficient according to working speed on row 3

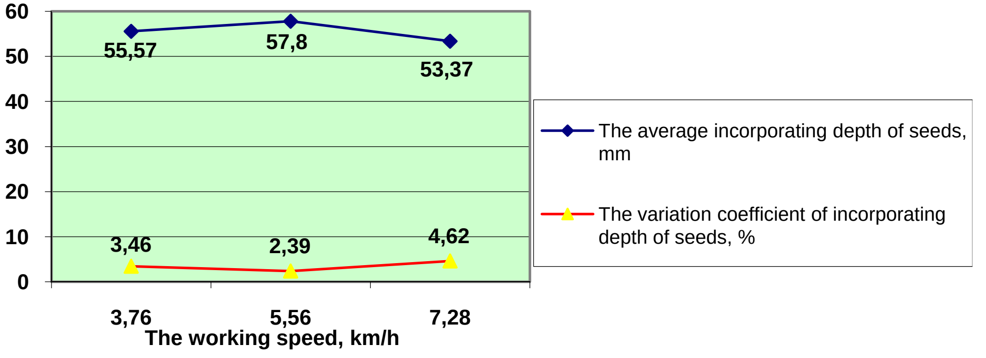


Fig. 12 Graphical representation of average depth and variation coefficient according to working speed on row 4

In figure 13 is graphically shown the variation of indexes determined for three speed stages of aggregate with New Holland T6070 tractor.

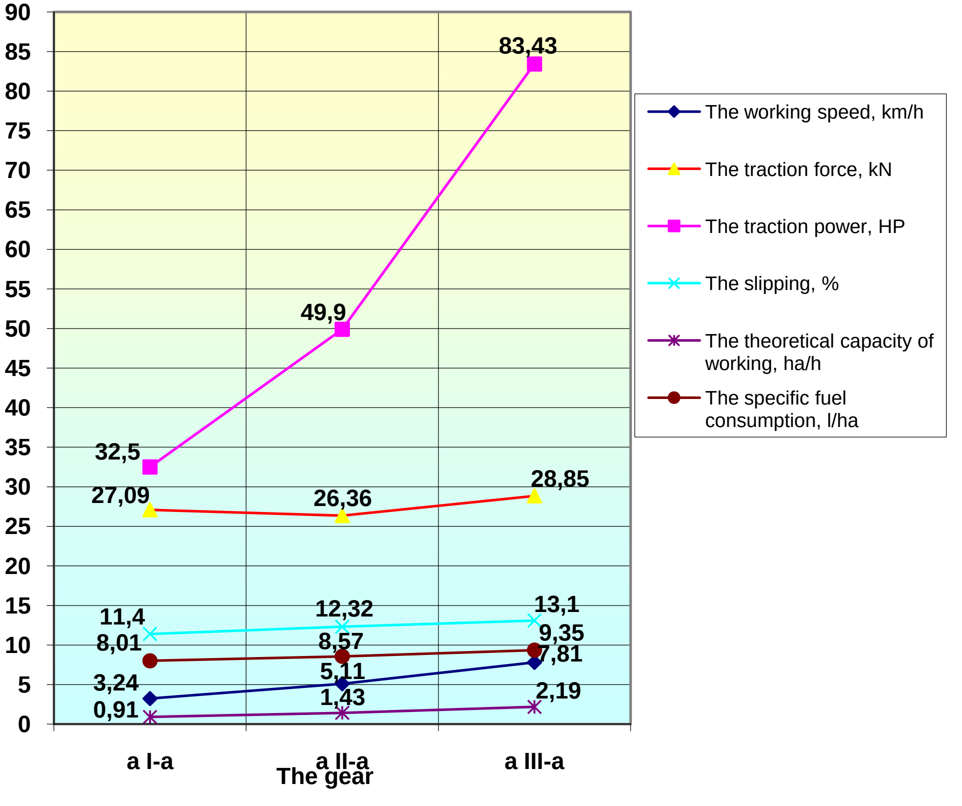


Fig. 13 Graphical representation of variation of indexes determined for three speed stages

Table 2 represents results of technological parameters during working in aggregate with 110 kW (150 HP) Lamborghini R1506 tractor on the agricultural field of ICDB Baloteşti, when sowing and fertilizing corn for silage, on a surface of 80 ha, in stubble field.

Table 2 Technological parameters during working in aggregate with Lamborghini R1506

Specification	**MU**	**Day when measurements were performed**				
		Day 1	**Day 2**	**Day 3**	**Day 4**	**Day 5**
Crop	-	corn	corn	corn	corn	corn
Average speed	km/h	5.52	5.48	5.56	5.58	5.46
Sown area	ha	10.2	9.8	10.4	10.6	9.6
Working time, T_1	min	342	331	344	348	326
Work rate, W_{ef}	ha/h	1.78	1.77	1.81	1.82	1.76
Work rate at the end of 8h/day period W_{07}	ha/h	1.46	1.43	1.49	1.48	1.40
Coefficient of technological safety, K_{41}	-	0.98	0.97	0.97	0.98	0.99
Coefficient of technological safety, K_{42}	-	0.92	0.90	0.91	0..95	0.90
Coefficient of reliability, K_4	-	0.90	0.87	0.89	0.93	0.88
Coefficient of time using for 8h/day period, K_{07}	-	0.75	0.74	0.76	0.76	0.79
Consumption of fuel per ha	l/ha	8.9	9.0	8.8	8.9	9.2

Fig. 14 A view on measuring of exploitation characteristics

After the experimental tests performed with technical equipment at corn crop setting we can make following conclusion

- In operating terms, the equipment has achieved working qualitative indexes which are in compliance with agro-technical requirements for sowing hoeing plants, stipulated in standard in force. This was proved in the suitable uniformity of seeds incorporating into the soil for all three working speeds, (minimum - 3.23 km/h, average -5.56 km/h and maximum 7.28 km/h), with higher values for working speed of 5.56 km/h.
- On the tests performed on 80 ha, the equipment had a good performance, achieving an average working capacity 1.78 ha/h at real working time in the average working speed of 5.52 km/h and the average fuel consumption 8.96 l/ha.

CONCLUSIONS

- The experimental researches have allowed validating the technical and technological solutions tackled when technical equipment parts were designed;
- The experimental results allow elaborating useful recommendation for farmer who apply this innovative technology of soil preparation and hoeing crops setting.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

EVALUATION OF SMALL SEEDS DISTRIBUTION UNIFORMITY

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SUMMARY

The paper presents a new method for evaluation of small seeds distribution (grass, clover, alfalfa) under laboratory conditions. The advantage of this method consists in a more quicker evaluation of seed distribution uniformity using computer aided techniques. The program developed in MathCad determines the number of seeds sown on a surface by converting an image taken from the sown surface to a binary numeral system, and after it will evaluate the seed distribution uniformity by specific mathematical formula inputted into the MathCad program.

Key words*: evaluation, distribution, seeds, sowing, uniformity.*

INTRODUCTION

It is well known that meeting the quality indicators when seeding, agricultural yield increases both qualitatively and quantitatively. To ensure the quality of seeding, some requirements should be meet:

- Seed quota per hectare;
- Incorporating seeds at the right depth;
- Ensuring optimal seeding density by respecting the proper distance between rows and uniformity of seed distribution. A lower density of plants uses only partially the solar and soil potential also a higher density generates competition between plants for water and nutrients, having the effect of decreased resistance and the occurrence of plant diseases.

Usually, to ensure the quality indicators of sowing, the sowing machine test is done in two stages: stationary - before sowing in the field, and after seeding. Nowdays, the uniformity of seeding is determined before seeding starts, depending on seed mass flow uniformity criterion. Modern precision drillers make exception to the rule of seed mass flow uniformity, these make grain by grain seeding. These are equipped with computers that allow user to choose the desired seeding density, which is indicated during the seeding process.

Having as an objective the rigorous assessment of planting density, a method is proposed to establish the uniformity of sowing, depending on the number of grains distributed in the sowing process, evaluation that can be used for most of small seeds seeded in rows.

METHOD

For achieving, the objective formulated above, three distinct phases must be accomplished:

- Calibration of measuring system;
- Experimental data collection;
- Processing of data using computer.

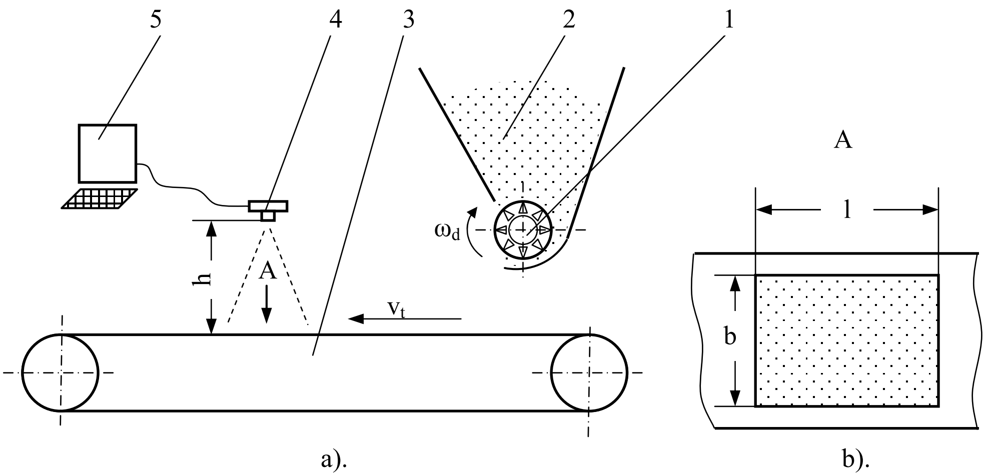


Figure 1 Test stand used for determining the uniformity of seed distribution; a) schematic representation; b) surface detail of captured image

The test stand of the seed meter (Fig.1) consists of:

a) Seed box (1) and seed meter (2) driven by an electric motor (ω_d - adjustable);
b) Seed collector system which consists of a conveyor belt (3), which simulates the motion of the sowing machine (V_t - adjustable);
c) Webcam (4) captures images with a frequency depending on the speed of the belt, and the angular speed ω_d of the seed meter previously set so duplicated images can

be avoided. Computer system (5) is used for storing images and experimental data processing.

The calibration of the measurement system consists in determining by trials, the position of the webcam to the conveyor belt. The height h is set so that the width b of the image is equal to the distance between rows (Fig. 2 and 3). In addition, this phase allows the determination of the surface of the sample unit Su and the mean horizontal projection surface corresponding to the So single seed (number of seeds No is known). To achieve this goal, the resolution of the webcam must be selected (x · y – pixels/imagine).

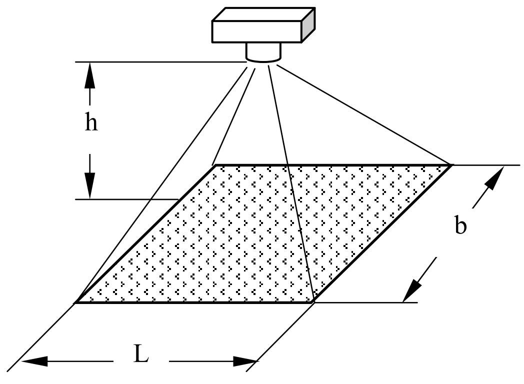


Figure 2 Illustration of sampling

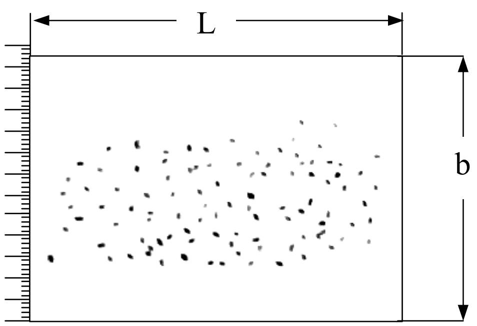


Figure 3 Capturated image <image 0.bmp>.

Experimental data collection consists in capturing the images (with the surface $S_u = b \cdot L, m^2$) after using the seed distribution stand shown in figure 1. Data processing using computers require two phases:

- storing images on computer;
- processing by the "DEval.mcd" computer program developed in MathCad.

For processing, images are saved in RGB color mode (24 bit/pixel). These are saved in BMP format, with name <image k.bmp>, where k = 1 ... z, and z is the number of samples taken.

A computer program was developed "DEval.mcd", using MathCad software features, version 14, for determining the uniformity of distribution of small seeds. The next section of the paper describes the program developed to evaluate distribution uniformity.

"DEVAL.MCD" COMPUTER PROGRAM

The program provides three steps: *initial data reading, block of computation* and *writing the results* as flowcharts like in figure 4:

Initial data reading

Inserting the captured image previously taken is done with command <*Insert*> from Mathcad program.

Distribution uniformity calculation

To read an array of the image and his corresponding attachment, it is considered that the image processing program recognizes any shade of color in the color intensity array: R (Red), G

(Grey) and B (Blue), expressed numerically by integer values which take numbers between 0 and 255, plus the x and y values that characterize each pixel position ($x = i, y = j$). For example, white, R = 255, G = 255 and B = 255, and the black R = 0, G = 0 and B = 0. For any other color from the palette of colors, RGB takes intermediate values. To attach the corresponding image to the matrix, the following operator is used:

M=READBMP (image k.bmp),

where: k = 0 for image taken when calibration of the system is done (N_C - known number of seeds); k = 1 ... z, z is number of sample.

In these conditions the matrix M_k takes the next form:

$$M_k = \begin{pmatrix} a_{1,1} & a_{1,2} & & a_{1,i} & & a_{1,x} \\ & & & \vdots & & \\ a_{j,1} & a_{j,2} & \dots & a_{i,j} & \dots & a_{j,x} \\ & & & \vdots & & \\ a_{y,1} & a_{y,2} & & a_{y,j} & & a_{x,y} \end{pmatrix} \tag{1}$$

where:

i = 1 ... x, y = 1 ... y, x and y defined by image resolution (x • y pixels / image);

k = 1 ... z - identifying the number of the sample.

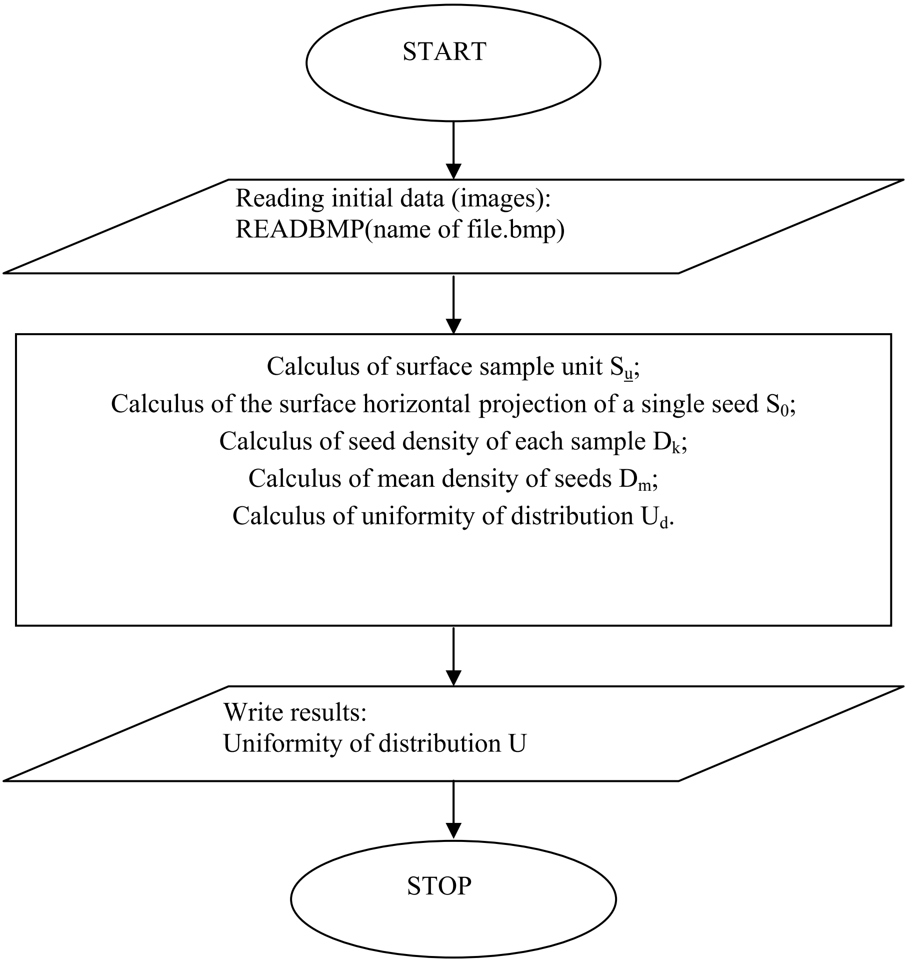


Figure 4 Logical block "DEval.mcd"

To simplify the matrix calculations, the 0 value is assigned to white color and 1 value for other colors:

$$M_k = \left| \begin{array}{ll} a_{i,j} \leftarrow 1, & if\,(a_{i,j} < 255) \\ a_{i,j} \leftarrow 0 & otherwise \end{array} \right. . \tag{2}$$

Thereby, we obtain a matrix consisting of elements with 0 and 1 value, where 1 represents each pixel covered by the seed. Using M_0 matrix corresponding to captured image at calibration of the measuring system, we obtain the area of the image S_u:

$$S_u = \frac{y}{x} \cdot b^2 \quad [m^2] \tag{3}$$

and S_o horizontal projection of the average mean size of seeds:

$$S_0 = \frac{\sum_{j=1}^{y}\sum_{i=1}^{x} a_{i,j}}{N_c} \cdot \frac{S_u}{x \cdot y} \quad [m^2], \tag{4}$$

where: $\sum_{j=1}^{y}\sum_{i=1}^{x} a_{i,j}$ represents the total number of pixels covered with seeds; $\frac{S_u}{x \cdot y}$ - the surface of a pixel [m^2].

Using images <image k.bmp> for k = 1 ... z, obtained by photographing the z probes, the determination of the correspondent number N_k of seeds is done with the relations of the form:

$$N_k = \sum_{j=1}^{y}\sum_{i=1}^{x} a_{i,j} \cdot \frac{S_u}{x \cdot y} \cdot \frac{1}{S_0} \tag{5}$$

To calculate the density D_k, in seeds/m^2, number of seeds N_k is multiplied with1/Su, so:

$$D_k = \sum_{j=1}^{y}\sum_{i=1}^{x} a_{i,j} \cdot \frac{1}{x \cdot y} \cdot \frac{1}{S_0} \tag{6}$$

The average density D_m, seeds/m^2, is described by the equation:

$$D_m = \frac{\sum_{k=1}^{z} D_k}{z}. \tag{7}$$

Using D_k density values expression determined with equation (6) and average density D_m described by equation (7), uniformity of distribution is calculated equation 8:

$$U_d = \left[1 - \sqrt{\frac{\sum_{k=1}^{z} (D_k - D_m)^2}{z-1} \cdot \frac{1}{D_m}} \right] \cdot 100, \quad [\%] \tag{8}$$

Writing the results

The results will be displayed both numerically and graphically. For the interpretation of results, the average density D_m and theoretical density D_t values are superimposed over the diagram of density variation D_k . This allows rapid interpretation of results.

Expressed numerically, results can be saved in a text file, which allows to save and later use in a database that can be useful in future research. It requires that the value of distribution uniformity of the number of seeds calculated with relation (8), to be within the limits allowed by standards. Limit value of quality indicators of sowing works, depending on crops, admitted in Romania, are presented in Table 1.

Table 1 Limit value of uniformity of distribution indicator for different crops

Indicator \ Crop	Wheat, peas	Rape	Alfalfa, clover, herbs
Seed distribution uniformity per seed machine, [%].	≥96	≥94	≥92
Sowing steadiness, [%].		≥97	
Seed distribution uniformity per row U_d, [%]		≥97	

APPLICATION

The method described above was subjected to practical testing. A seed meter for wheat was used. The main characteristics of the seed meter and initial conditions are presented in table 2 and 3.

Table 2 Operation conditions imposed

Crop	alfalfa
Type of seed meter	Studded roller
Seed quota	20 kg/ha
Theoretical density D_t	1000 seeds/m^2
Distance between rows – b	0,125 m
Conveyor belt speed 7,2 km/h - V_t	2 m/s
Angular speed of the seed meter - n_d	rot/s - variable

Using the "Deval.mcd" program described in the previous section, obtained results are showen in table 4 and 5. The results analyzed for the condition imposed, described in table 2 and 3, allows to formulate the following:

- Uniformity of distribution of seeds per row, *Ud* = 98 662%> 97% is within the imposed limits;

- Seed density, expressed in *seeds/m²*, has a value 6.3% higher than the theoretical (D_t = 1000 *seeds/m²*), for which adjustments were made for the sowing machine. This deficiency leads to an increase of seeding costs. Such a result needs a restore of the machine settings, and a retest until the average density is between the limits $D_t \pm 2\%$;

Table 3 Initial data

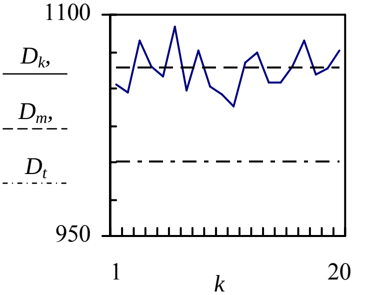
Image resolution (x·y)	(320 · 240) pixeli
Frequency of captured image	1 image/2 seconds
Number of seeds used for calibration - N_c	100 seeds
Number of probes – z	20

CONCLUSIONS

The developed method for determining the uniformity of distribution described in the paper has the advantage of assessing the uniformity of distribution density, compared with current methods that take into account the uniformity of the mass flow of seeds.

Table 4 Density values

Density values/m²			Results
Probe	Symbol	Value	Average density – $\mathbf{D_m}$, *Seeds/m²*
1	D_1	1053	**1063**
2	D_2	1047	
3	D_3	1082	Distribution uniformity - $\mathbf{U_d}$, %
4	D_4	1065	
5	D_5	1058	**98,662**
6	D_6	1092	
7	D_7	1049	**Distribution uniformity chart**
8	D_8	1076	
9	D_9	1052	
10	D_{10}	1046	
11	D_{11}	1038	
12	D_{12}	1068	
13	D_{13}	1074	
14	D_{14}	1054	
15	D_{15}	1054	
16	D_{16}	1065	
17	D_{17}	1082	
18	D_{18}	1059	
19	D_{19}	1064	
20	D_{20}	1076	



Using modern digital recording systems and image processing data, time spent for testing seeding drills is reduced. The proposed method is recommended primarily for research in laboratory conditions, and for evaluating the performance of different types of seed meters for studying distribution and functional parameters influence over the uniformity of distribution.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

STRAW CEREALS OPTIMUM SOWING RATE OPTIMIZING DISTRIBUTION OF CENTRALIZED METERING DRILLS

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SUMMARY

The process of metering and distribution of seeds, has a decisive influence on the main indices of quality sowing machine: flow uniformity, sowing rate, uniform distribution of working width, uniformity of distribution line. Because of this, improvement of drills focused mainly on improving distribution devices, which is the main working bodies of drills and how they work depends on the quality of sowing. Use distribution devices with centralized measuring to reduced weight for increased capacity seed hopper and aggregate productivity sowing.

Optimization of distribution of straw cereals drills with centralized measuring is to find a balance between the main control parameters of the distribution device, and between the ratio of the flow metering device grains and the speed of the machine work to achieve agrotechnics sowing rules required for each type of crop in hand. To this end, it was developed a mathematical model that describes the sowing rate variation depending on sowing machine speed and on active length of the groove measuring device, mathematical model which was validated using experimental data.

Key words*: sowing rate, optimizing, drills, mathematical model*

INTRODUCTION

The distributing device of centralized dosing and pneumatic distribution sowing machines (Fig. 1) consists of a centrifugal fan 1, a cylinder of metering device with grooves mounted in a metal box attached to the bottom of seed hopper 2, a vertical tube for pneumatic transport 3 and a distribution head 4.

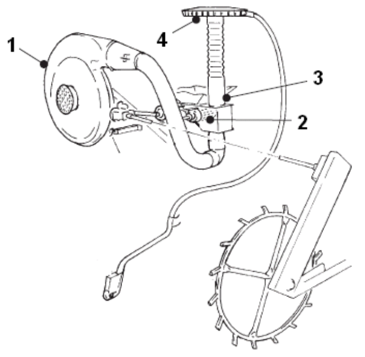

Fig. 1 The components of the device with centralized metering and pneumatic distribution: 1– fan; 2 – metering device; 3 – vertical tube; 4 - distribution head

METHODS

Mathematical modeling of sowing rate function

The seeds volume discharged by the metering device, to a rotation of the fluted roller is determined by relation:

$$V_d = 1,65 \cdot A \cdot L_c \cdot z \cdot \psi \text{ [m}^3\text{/rev] , [5]} \quad (1)$$

where : A is is the cross-sectional area of the flutes in m^2 ; L_c - active length of the groove, in m; z – grooves number; ψ - seed filling groove coefficient (ψ = 0,93÷0,98 for small seeds, ψ = 0,60÷0,85 for medium seeds and ψ = 0,45÷0,80 for big seeds).

The seed flow rate of the metering device with fluted roller necessary for a sowing rate N is given by relation:

$$Q_s = V_d n_d \gamma_s = \pi D n_r B_m \frac{N}{10^4} \text{ [kg/min], [5]} \quad (2)$$

where: n_d is the dosing device speed; γ_s – seeds specific mass; D - the wheel drive diameter, in m; n_r – the wheel drive speed, in rot/min; B_m - machine working width, in m; N – sowing rate, in kg/ha;

From (2) relation results the seeding rate expression, as:

$$N = \frac{V_d \cdot \gamma_s \cdot 10^4}{\pi \cdot D \cdot B_m \cdot i_t} \text{ [kg/ha],} \quad (3)$$

where i_t is the ratio between drive wheel and dosing device.

It is introduced in (3) relation the (1) expression of the volume of seeds distributed to a rotation of the grooved cylinder and the seeding norm function $N(L_c,v)$ is defined, as:

$$N(L_c,v) = \frac{1,65 \cdot A \cdot z \cdot \gamma_s}{\pi \cdot B_m \cdot D \cdot i_t} \cdot \psi \cdot L_c \cdot 10^4 \text{ [kg/ha]} \tag{4}$$

The (4) equation shows that if the parameters A, z, γ_s, B_m, D şi i_t are constant, then the rate N does not depend on working speed. From experimental research conducted by authors, was found that for the increase of the working speed for a constant flow of seeds, the norm value applied decreases, which the theory does not show. However, experimental data show that the increase of the seeding norm with the fluted roller active length has a slightly non-linear aspect.

Given these observations, we appealed for modeling, to the approximation rational function, with the general form:

$$N(L_c,v) = \sum_{i=0}^{n} \sum_{j=-k}^{m} a_{ij} {L_c}^i v^j \tag{5}$$

As shown in equation (5) where made for speed and negative integer exponents to model decreases with increasing speed sowing. Active length of the groove is taken into account only positive integer exponents. The method of calculation is the method of least squares, shape approximation (5) leading to a minimized functional form relatively simple:

$$F(a_{ij}) = \sum_{l=1}^{n} \left(\sum_{i=0}^{n_{L_c}} \sum_{j=-k}^{n_v} a_{ij} {L_{cl}}^i {v_l}^j - N_l \right)^2 \tag{6}$$

for the system of equations obtained by canceling the partial derivative is linear. Solving the system leads then to obtain the coefficients a_{ij}.

Using this method is a form of polynomial time (with a finite number of terms to be specified), that according to the approximation that minimizes the functional (6). Functional (6) is actually defined on a infinite variety of shapes of features, but in this work I stopped in terms of maximum 2 in L_c and minimum -2 in v. In fact, considering the higher degree terms (mode) is not necessary due to the shape dependence suggested by experimental data.

For mathematical modeling of the function (4) were chosen two versions of rational functions (N_1 and N_2) and after comparing their approximation degree, was chosen the option that best approximates the theoretical data. Based on the constructive solutions analysis for dosing device with grooved cylinder, was chosen a theoretical range variation of the active groove length between 0.01÷0.1 m, and under the agro-technical requirements which a cereals sowing machine should meet, was chosen a theoretical variation range of the work speed between 1.38÷2.77 m/s (5÷10 km/h).

Variant I. Rational approximation function is:

$$N_1(L_c, v) = a_0 \cdot \frac{L_c}{v} + a_1 \cdot \left(\frac{L_c}{v}\right)^2 \quad (7)$$

After calculating the a_{ij} coefficients the function (7) becomes:

$$N_1(L_c, v) = 1,266 \cdot 10^4 \frac{L_c}{v} - 1,149 \cdot 10^5 \left(\frac{L_c}{v}\right)^2 \quad (8)$$

whose approximation degree is $G_1 = 7,744 \cdot 10^3$.

In figure 2 is given the comparative graphic representation between the theoretical sowing rate values and the ones obtained by applying the rational approximation function (8) theoretical values for L_c and v.

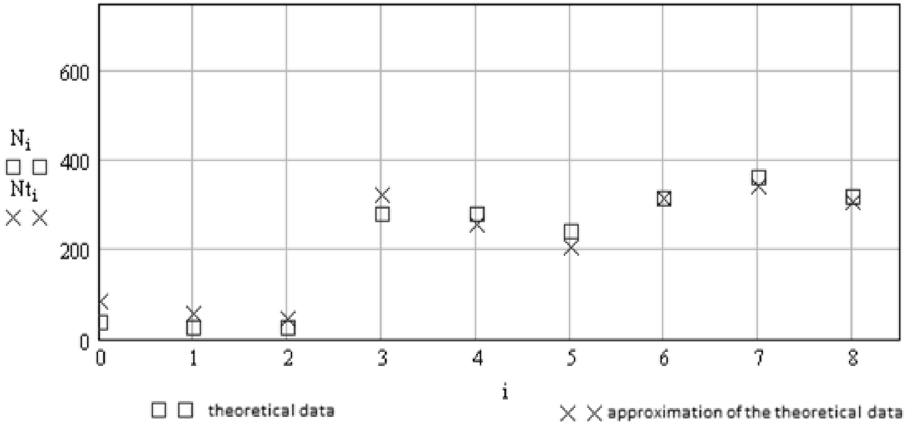

Fig. 2 Comparative graphic representation between sowing rate theoretical values and the ones obtained with rational approximation function $N_1(L_c, v)$

Variant II Rational approximation function is:

$$N_2(L_c, v) = a_0 \cdot L_c + a_1 \cdot \frac{1}{v} + a_2 \cdot L_c^2 + a_3 \cdot \frac{1}{v^2} + a_4 \cdot \frac{L_c}{v} + a_5 \cdot \left(\frac{L_c}{v}\right)^2 . \quad (9)$$

After calculating the a_{ij} coefficients the function (8) becomes:

$$N_2(L_c,v)=3,358\cdot10^3\cdot L_c-85,568\cdot\frac{1}{v}-1,891\cdot10^4\cdot L_c^2+0,69\cdot\frac{1}{v^2}+8,704\cdot10^3\cdot\frac{L_c}{v}-7,662\cdot10^4\cdot\left(\frac{L_c}{v}\right)^2 \quad (10)$$

whose approximation degree is $G_2=930,003$.

Figure 3 shows the comparative graphic representation between the theoretical sowing rate values and the ones obtained by applying the rational approximation function (10) theoretical values for L_c and v.

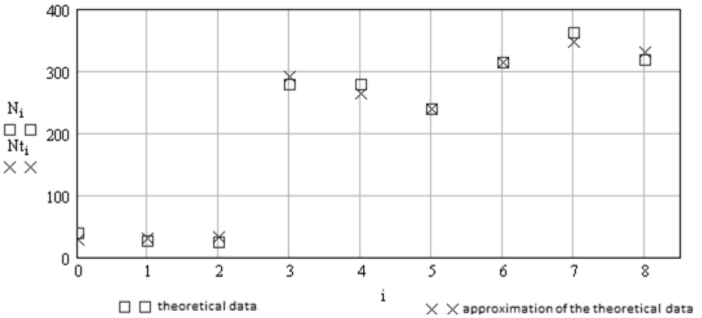

Fig. 3 Comparative graphical representation between theoretical sowing rate values and the ones obtained with the rational approximation function $N_2(L_c, v)$

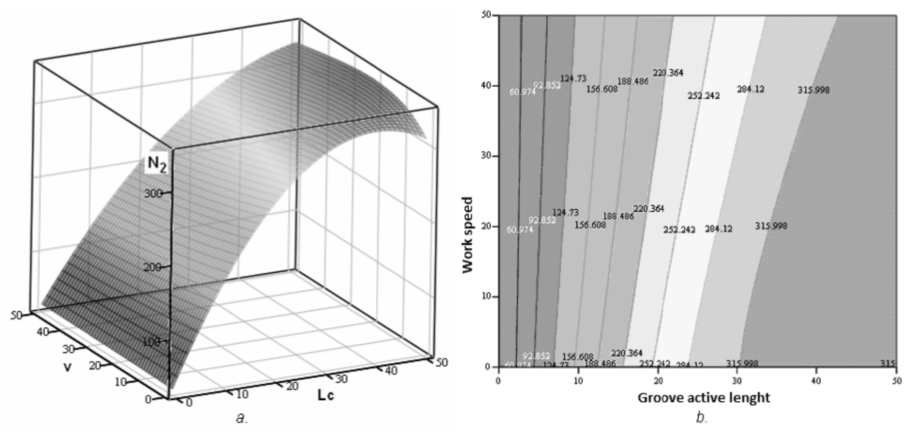

Fig. 4 Variation diagram of the rational approximation function $N_2(L_c, v)$; *a* - surface generated for $N_2(L_c, v)$; b – projection of $N_2(L_c, v)$ surface in plan, viewing constant sowing rate

Comparing the results for the approximation degree, shows that $G_2<G_1$, namely, the value of the function approximation degree $N_2(L_c, v)$ is less than the approximation degree

of the function $N_1(L_c, v)$. In addition, analyzing the graphs in figures 2 and 3, there is a better approximation of the theoretical data by the function $N_2(L_c, v)$ whose 3D variation diagram is shown in figure 4.

RESULTS AND DISCUSSION

Mathematical model validation of the sowing norm based on experimental data

In order to validate the mathematical model of the sowing norm, rational approximation function chosen in the previous paragraph, still noted by $Nf(L_c,v)$, as best to approximate the theoretical data, was applied to experimental data obtained for the sowing norm, for each seed individually.

For the ***wheat*** seed, the function describing the norm dependence on the groove's active length and the work speed is:

$$Nf(L_c,v) = 1,011\cdot 10^4 \cdot L_c - 289,992\cdot \frac{1}{v} - 5,695\cdot 10^4 \cdot L_c^2 + 390,921\cdot \frac{1}{v^2} - 5,417\cdot 10^3 \cdot \frac{L_c}{v} + 1,397\cdot 10^5 \cdot \left(\frac{L_c}{v}\right)^2 \tag{11}$$

In figure 5 are graphically represented the experimental norms values for the wheat seed and the norm values obtained applying the (11) function's experimental values for L_c and v. There is a good approximation of experimental data by function (11).

Fig. 5 Comparative graphical representation between experimental norm values and the ones obtained with the approximation function, for wheat seed

3D diagram of sowing norm variation modeled using function (11), is shown in figure 6, and the normal variation for each setting parameter is shown in figures 7 and 8.

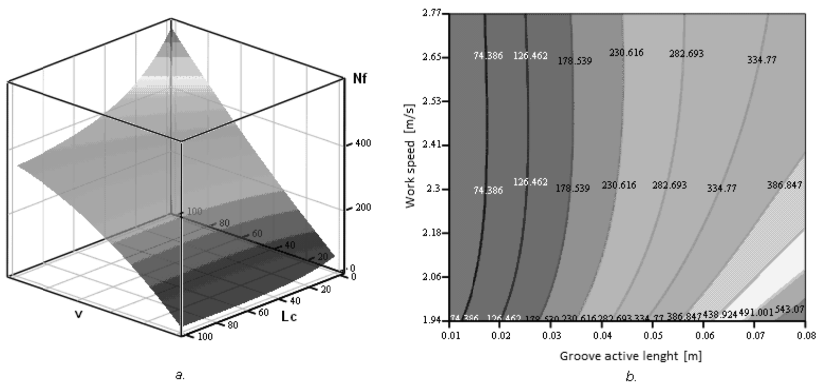

Fig. 6 Norm variation diagram, for wheat seed; a – surface generated for Nf(L_c,v)*;* b – norm control curves depending on the groove active length and the working speed

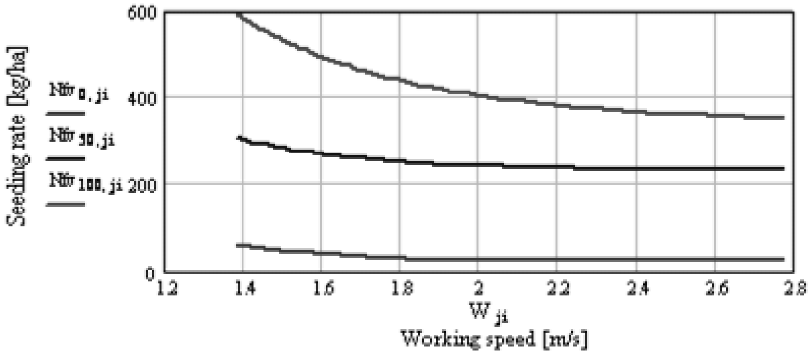

Fig. 7 Norm variation diagram depending on the working speed

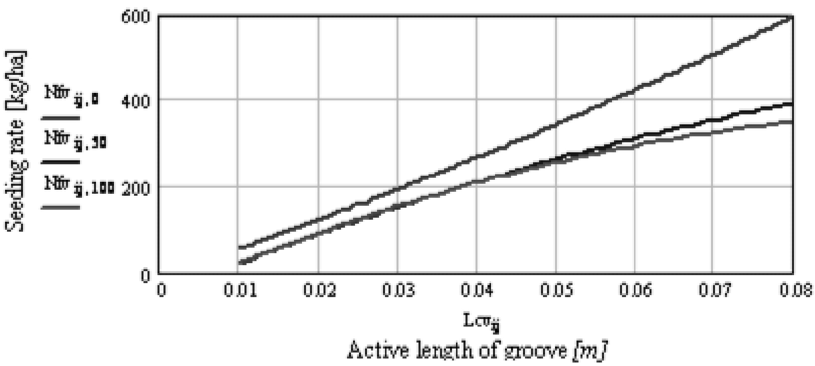

Fig. 8 Sowing norm variation depending on the groove active length

Analyzing the graphs in figures 7 and 8 can be observed that the sowing norm decreases with the increasing of the working speed, to the same amount of seed flow given by the active length of grooves and increases with the seed flow increase for a constant working speed, which confirms the initial hypothesis.

For ***alfalfa*** sowing, the function describing the length dependence of active groove shape and speed is:

$$Nf(L_c, v) = -150.336 \cdot L_c + 3,264 \cdot 10^{-5} \cdot \frac{1}{v} + 1,768 \cdot 10^3 \cdot L_c^2 + 0,052 \cdot \frac{1}{v^2} + 2,034 \cdot 10^3 \cdot \frac{L_c}{v} - 3,044 \cdot 10^4 \cdot \left(\frac{L_c}{v}\right)^2 \tag{12}$$

Figure 9 are plotted the experimental values for sowing alfalfa norms and values obtained by applying the rules of function (12) experimental values for L_c and v. There is a good approximation of experimental data by function (12).

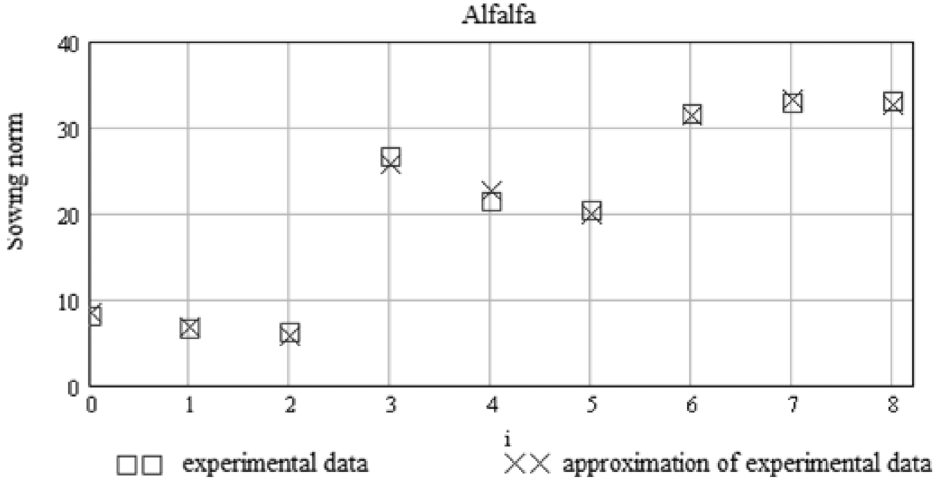

Fig. 9 Graphical representation of experimental procedures and comparative values obtained with the approximation function for alfalfa sowing

3D diagram of variation of sowing norm modeled using function (12) is shown in figure 10 and the normal variation for each parameter setting is shown in figures 11 and 12.

After analyzing the graph in Figure 11, we have found up that at minimum and average values of the active length of the fluted roller the sowing rate decreases with increasing working rate, it has a slight speeding up of work for the maximum length of active groove, then returns to the downward trend.

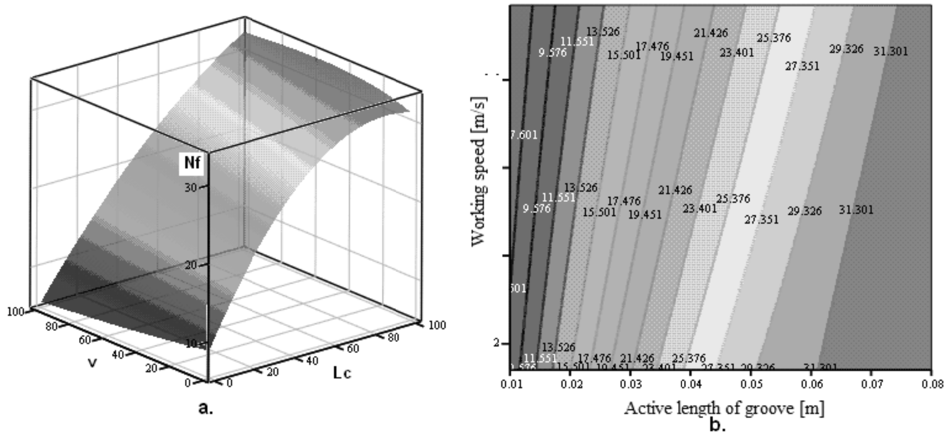

Fig. 10 Diagram of variation of the norm for sowing alfalfa*;* a – surface generated for $Nf(L_c,v)$*;* b – adjustment of the standard curves according to the grooves active length and working speed

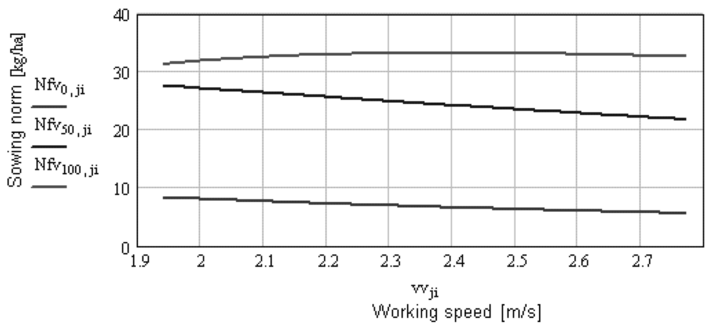

Fig. 11 Seed normal variation depending on the speed of work

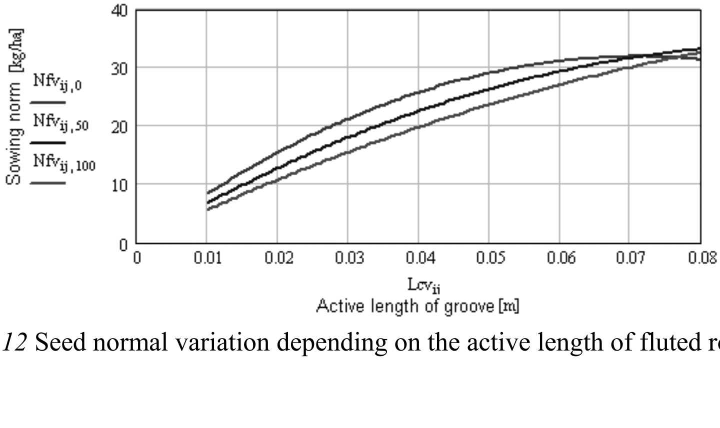

Fig. 12 Seed normal variation depending on the active length of fluted roller

To verify the theoretical hypothesis, according to which the seeding rate decreases with increasing sowing speed and to validate the mathematical model were studied in comparison standard charts of variation of norm with speed work, based on experimental data and graphs of variation of norm with working speed obtained by applying theoretical mathematical model of experimental data.

Observations which can be drawn from the comparative study are:

- the sowing norm tends to decrease with increasing speed; at a constant seed flow rate is observed in 83.33% out of the results obtained both experimentally and by mathematical modeling;
- if the remaining 16.67% includes the maximum flow alfalfa seed when sowing norm has a tendency to increase with increasing working speed.

In conclusion, the initial hypothesis is verified and the theoretical mathematical model of sowing norm is validated, experimental data confirming its usefulness and correctness.

Norm variation in comparison with the working speed, based on experimental data

Norm variation in comparison with the working speed, obtained by mathematical model

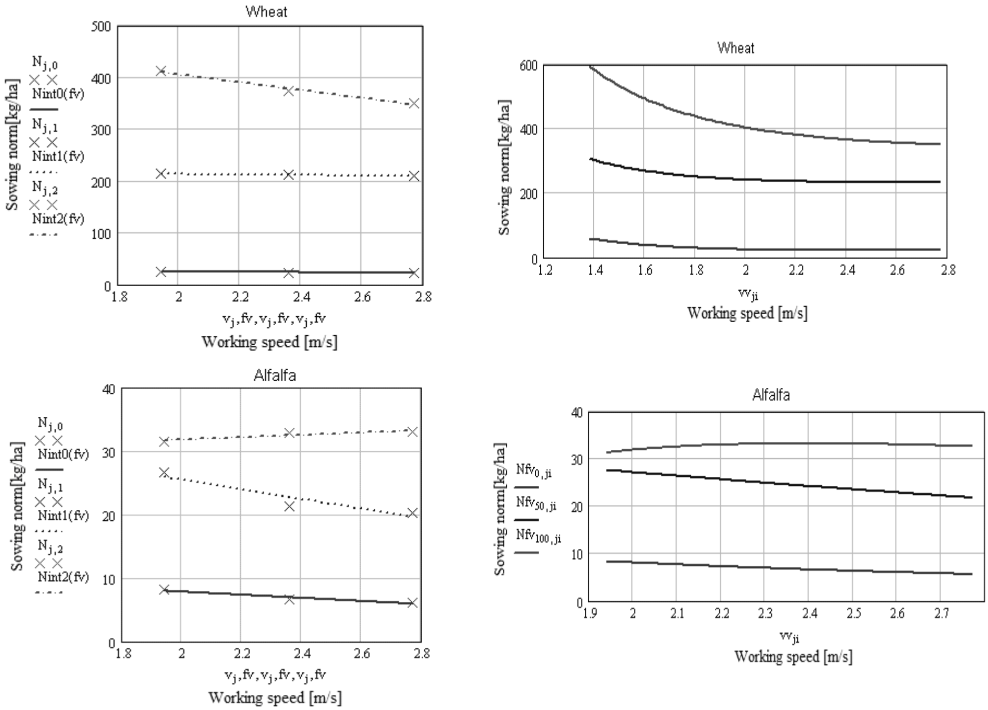

Fig. 13 Graphical comparison between sowing norm based on experimental data (left side) and mathematical model (right side)

CONCLUSIONS

- The seeds dosing and distribution determine the quality working indices of mechanical-pneumatic equipment - and implicitly those of sowing machine, therefore the calculation and sizing of these devices are very important;
- Since the experimental data performed show that sowing norm decreases with increasing working speed, at constant flow of sowing, starting from this assumption have been defined two types of rational approximation functions that have taken in consideration for speed also negative exponents to model the norm decrease with increasing speed;
- Following the graphs comparing of the results obtained for the two functions and their degrees of approximation, the optimum mathematical modeling variant of theoretical sowing norm has been chosen depending on the active length of groove and working speed;

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 631. 331.3
Stručni rad
Expert paper

RESEARCHES REGARDING THE OPTIMIZATION OF THE SEEDS HOPPER FROM THE UNIVERSAL SEEDS DRILL

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SUMMARY

This paper presents a procedure for the calculus and dimensional optimization of a seeds hopper volume from a universal seeds drill. First, the meaning and importance of some constructive parameters taken into account in the procedure are fully explained and exemplified. Then, the mathematical algorithm underlying the hopper's cross-sectional area maximization is developed.

The procedure is applied on a hopper from a real seeds drill. It is important to note that the hopper's volume has been already maximized by the designer. Therefore it will be tested whether the proposed procedure is capable to add value to the method used by the designer.

Under these conditions, it is found that the proposed method has further succeeded an increase in cross-sectional area from 0,89 m2 to 0,93 m3. Considering that the total length of the hopper in this example is 3,086 m, an overall increase in volume of 12,3 L is obtained.

Key words*: seeds drill, seeds hopper, volume optimization*

INTRODUCTION

To ensure food security of population in the context of sustainable agriculture, it is necessary to make serious efforts also in the field of universal seeds drills in order to make technical equipment performant, highly reliable, and characterized by an optimal construction.

Seeding is one of the most important agrotechnical works and consists of uniform dosage of seeds per unit area and introduction of seeds in the soil at a certain depth, both being operations which should be given maximum attention.

One of the criteria underlying the choice of a particular drill is the seeds hopper capacity. On the universal drills, seeds hopper is common to all or to a group of coulters.

MATERIAL AND METHOD

Universal drills are used for establishing cereal crops. Therefore, they must provide uniform distribution of different seeds with different physical and mechanical properties.

An imposed agro-technical requirement is to provide increased working capacity. This requirement may be fulfilled if there is a correlation between drill's constructive parameters and the power available at the energy source, among parameters being included the volume of seed hopper.

Cross-sectional shape of the seed box is adopted based on physical and mechanical properties of seeds, basic forms being trapezoidal or triangular (Fig. 1).

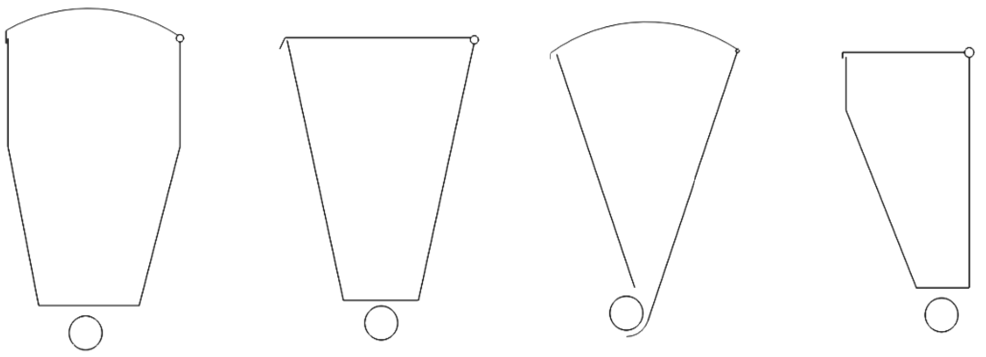

Fig. 1 Some basic forms of seeds hoppers

Seed hopper's volume is determined based on the maximum sowing rate or on minimal bulk density, and it can be calculated by means of the following equation:

$$V_c = B_{ms} V_0 \tag{1}$$

where: B_{ms} - working width of universal seeds drill (m); V_0 – specific volume on working width unit of drill (m^3/m), $V_0 = 0.06 \ldots 0.3\ m^3/m$.

Cross-sectional area *A* of the seeds hopper is adopted as equal in value to the specific volume, so $A = V_0$. Minimum width at the top of the box is determined so as to ensure minimum height required for the formation of seeds flow channel through the outlet towards seeds metering devices.

Due to the complexity of the phenomenon of seed flow, it was necessary to establish mathematical correlations between the geometric characteristics of seeds and the hopper. Flow type (continuous or discontinuous) and seeds exhaust speed from the hopper through the outlet, are dependent on the hydrostatic pressure developed by the mass of seeds inside the hopper. In the seeds flow analysis, should be considered both frictional forces between grains and side walls of the hopper and friction between layers of seeds.

In case of a granular material, the hydrostatic pressure is determined by means of equation (2):

$$p = \rho \cdot g \cdot h \cdot k \tag{2}$$

where: ρ – seeds apparent density (kg/m^3), h - thickness of material above the considered point, k – mobility coefficient, with values between 0,2 and 0,6 (also known as pressure attenuation coefficient due to lower mobility of seeds compared with a liquid).

Seeds mobility coefficient depends on internal friction of seeds, and can be calculated with equation (3):

$$k = \frac{1-\sin\varphi}{1+\sin\varphi} \tag{3}$$

where φ is the slope angle of the seeds hopper.

It is found that hydrostatic pressure is influenced by the natural slope angle, which is a constructive characteristic of the seeds hopper.

The correlation between the angle of inclination of the lower part of the hopper and seeds mass pressure is determined by the relation:

$$p = \frac{\rho \cdot g \cdot h}{\mu \cdot h}\left(1 - \frac{1}{e^{\frac{\mu k}{R}h}}\right) \tag{4}$$

where: μ - coefficient of friction between grains and walls of the box; R - hydraulic radius ($R = A / L$, where A is cross-sectional aria of the hopper in m^2, and L is the perimeter of the lateral surface of seeds elementary volume, in m).

The angle of inclination of the lower part of seeds hopper (flow angle) depends on humidity, density and mass per storage volume of seeds, these properties depending on each other (Table 1). The feeding process of seeds metering devices is influenced by the natural slope angle (Table 2).

Flow angle (the tilt angle of a flat surface on which are seeds, for them to slide or roll) must be taken into account when designing the lower part of seeds hopper (Table 3).

Table 1 The influence of humidity on density and hectoliter weight

Nr. crt.	Product	Humidity u (%)	Density ρ (kg/m3)	Hectolitre weight (kg/hl)
1.	Wheat	7,3	1400	79,0
		11,0	1360	79,0
		14,1	1300	79,6
		17,1	1290	73,7
		19,3	1280	70,3
2.	Barley	11,6	1240	71,5
		15,2		65,9
		21,8		63,8
		26,0		62,5
3.	Raw rice	12	1110	58,6
		14	1140	58,8
		16	1173	60,5
		18	1200	61,5
4.	Paddy rice	12	1275	54,9
		14	1270	55,7
		16	1260	54,9
		18	1240	52,8

Table 2 Variation of natural slope angle with cereal seeds humidity

Nr. crt.	Product	Humidity u (%)	Natural slope angle α (°)
1.	Wheat	15,3	30
		22,1	38
2.	Rye	11,1	23
		17,8	34
3.	Barley	11,9	28
		17,8	32
4.	Oat	14,6	32
		20,7	41

Table 3 Flow angle on different materials

Nr. crt.	Seeds	Natural slope angle α (°)	Flow angle φ (°)			
			on wood	on canvas	on steel sheet	on galvanized sheet
1.	Wheat, rye	23-28	20-26	-	16-17	24-27
2.	Barley	28-45	21-23	-	17-18	-
3.	Oat	28-54	18-36	25-55	15-16	21
4.	Rice	37-45	24	-	17-18	21-22

RESULTS AND DISCUSSION

Considering the above discused structural elements that decisively influence the design procedure of seeds hoppers, following there will be presented a method of maximizing the volume of a hopper from a universal drill.

The procedure will be applied on a hopper from a real seeds drill, whose irregular polygon-shaped section is shown in Figure 1, for which is intended to maximize the area, however taking into account the following conditions:

- angles α_1 and α_2 will be kept unchanged, in order not to change seeds flow towards metering devices;
- the overall dimensions *H* and *B* will be kept unchanged (H provides visibility to the rear of the tractor; increasing the *B* value may result in exceeding the legal maximum overall longitudinal dimension of the tractor-seeder aggregate).

It is important to note that the hopper volume has been already maximized by the designer. Therefore the proposed procedure will test whether it is capable to add value to the method used by the designer.

If one choose a coordinate system as in Figure 1, and the vertexes of the irregular polygon are denoted by A_i (x_i, y_i), i = 1...6, the above restrictions can be translated mathematically as follows:

$$x_1 = 0;\ x_3 = B;\ x_4 = B;\ x_6 = 0;\ y_2 = 0;\ y_5 = H;\ y_6 = H.$$

Variables that can be modified are x_2, x_5, y_1, y_3 and y_4.

The following dependency equations can be deducted from figure 1:

$$y_1 = x_2 \cdot \tan \alpha_1$$
$$y_3 = (B - x_2) \cdot \tan \alpha_2 \qquad (5)$$

Joining the origin of the coordinate system with A_i vertexes, triangles OA_1A_2, OA_2A_3, OA_3A_4, OA_4A_5 si OA_5A_6 are obtained.

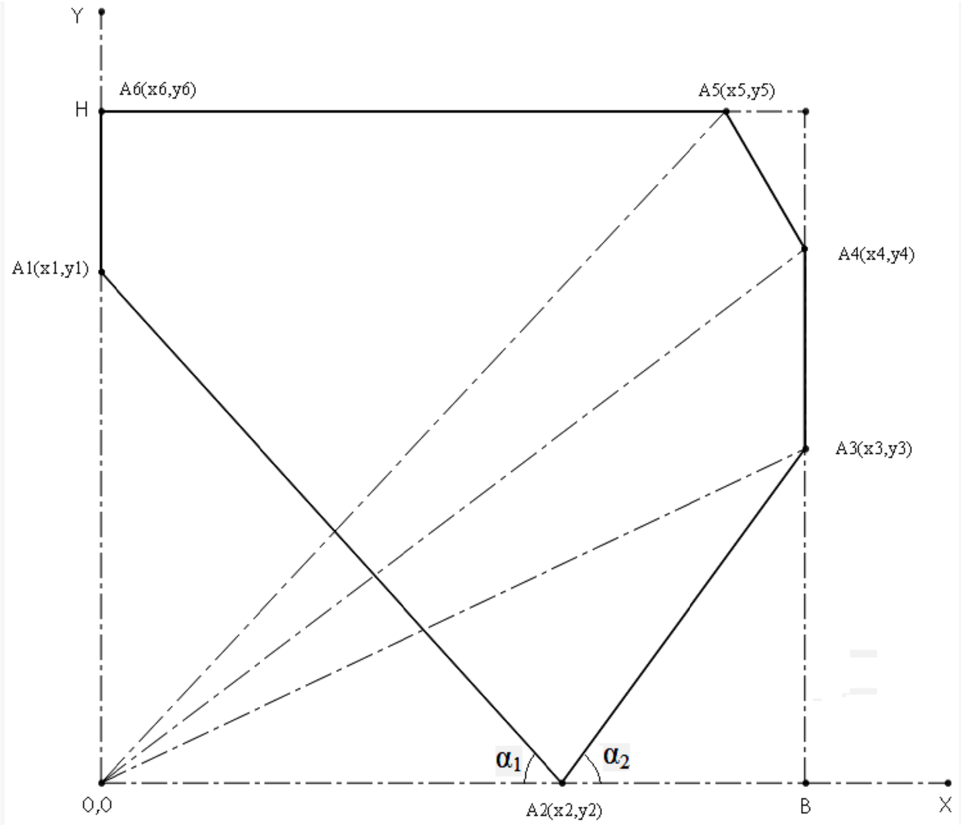

Figure 1 Initial shape of the cross-sectional hopper's area

Traveling onto the perimeter of the polygon in clockwise direction, starting from A_1, for each side of the polygon that is oriented downwards and to the right, the area of the corresponding triangle will be considered with negative value. Each triangle's area is calculated with equation (6):

$$A_i = 0,5\left(\begin{vmatrix} 0 & 0 & 1 \\ x_i & y_i & 1 \\ x_i+1 & y_i+1 & 1 \end{vmatrix}\right) \tag{6}$$

So

$$A_i = 0,5\left(x_i y_{i+1} - x_{i+1} y_i\right) \tag{7}$$

Therefore, the area of the polygon can be calculated with the relation:

$$A = \frac{1}{2}\sum_{i=1}^{n}(x_i y_{i+1} - x_{i+1} y_i) \tag{8}$$

In this case:

$$A = \frac{1}{2}\sum_{i=1}^{7}(x_i y_{i+1} - x_{i+1} y_i) \tag{9}$$

where $i=7$ is equivalent with $i=1$, in order to close the contour.

After the sum is developed, equation 10 is obtained:

$$A = \frac{1}{2}(x_1y_2 - x_2y_1 + x_2y_3 - x_3y_2 + x_3y_4 - x_4y_3 + x_4y_5 - x_5y_4 + x_5y_6 - x_6y_5 + x_6y_1 - x_1y_6) \tag{10}$$

Given the values of constants and equations (5), mathematical relation (10) becomes:

$$A = \frac{B(H - 2B\tan\alpha_2)}{2} + \frac{1}{2}[2Bx_2\tan\alpha_2 - x_2^2(\tan\alpha_1 + \tan\alpha_2) + By_4 - x_5y_4 + Hx_5] \tag{11}$$

The partial derivatives of the area A in relation to variables x_2, x_5 and y_4 are equaled to zero in order to calculate the parameter values that maximizes the cross-sectional area of the hopper:

$$\frac{\partial A}{\partial x_2} = \frac{1}{2}[2B \cdot \tan\alpha_2 - 2x_2(\tan\alpha_1 + \tan\alpha_2)] = 0 \tag{12}$$

$$\frac{\partial A}{\partial y_4} = \frac{1}{2}(B - x_5) = 0 \tag{13}$$

$$\frac{\partial A}{\partial x_5} = \frac{1}{2}(H - y_4) = 0 \tag{14}$$

From equations (13) and (14) it results:

$$x_5 = B;\ y_4 = H \tag{15}$$

Extract x_2 from equation (12):

$$x_2 = \frac{B \cdot \tan\alpha_2}{\tan\alpha_1 + \tan\alpha_2} \tag{16}$$

Taking into account relations (5), y_1 and y_3 are obtained:

$$y_1 = y_3 = \frac{B \cdot \tan\alpha_1 \cdot \tan\alpha_2}{\tan\alpha_1 + \tan\alpha_2} \tag{17}$$

In the table 4there are given the values of coordinates x_i and y_i before and after optimization.

Figure 2 shows the comparison between the two sections of the hopper, before and after maximizing surface by means of the proposed method.

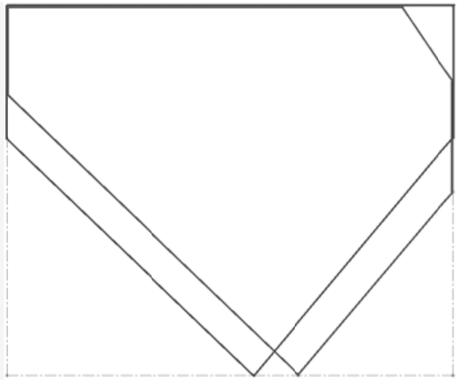

Figure 2 Section shapes, before (blue) and after (red) optimization

Table 4 Values before and after optimization

Parameter	Values before optimization (mm)	Values after optimization (mm)
x_1	0	0
y_1	871	736,4
x_2	784	663
y_2	0	0
x_3	1198	1198
y_3	570	736,4
x_4	1198	1198
y_4	910	1146
x_5	1062	1198
y_5	1146	1146
x_6	0	0
y_6	1146	1146

It is found that, although the volume of the hopper was already considered maximized by the designer, the proposed method has further succeeded an increase in cross-sectional area from 0,89 m^2 to 0,93 m^2. Considering that the total length of the hopper in this example is 3,086 m, an overall increase in volume of 12,3 liters is obtained.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

RESEARCHES REGARDING THE INFLUENCE OF WORKING SPEED ON THE HOE DRILLS SEEDING ACCURACY

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SUMMARY

In the global context of making more efficient the relation between resources and needs, the agriculture still has more areas that have not been researched enough. The mechanical seeding of weeding plants is an important is an important link through which man controls the plants' biological cycle, used for their contribution in providing food.

Factors affecting the accuracy of sowing are: seeds type, local humidity and temperature during sowing, constructive parameters of the sowing equipment, the fullness of the seeding box, equipment speed, adjustment of the distributor, equipment tilt, parasitic movements of grain.

This paper deals with establishing a relationship between the hoe drills working speed and sowing accuracy, as well as determining the optimal speed according to the number of plants per unit area.

Key words: *hoe drill, working speed, seeding accuracy*

INTRODUCTION

In the global context of making more efficient the relation between resources and needs, the agriculture still has more areas that have not been researched enough. The mechanical seeding of weeding plants is an important is an important link through which man controls the plants' biological cycle, used for their contribution in providing food. The importance of mechanized seeding is that enables transposition in natural conditions, on the field, of what plant growing research studies and finalizes in laboratories, regarding the factors that influence plant development in order to achieve maximum benefits.

Precision hoe drills are intended for pockets seeding, at different distances between rows (> 35 cm) and between pockets of seeds (2.5 - 140 cm). One of the agrotechnical requirements that these machines must meet, is to keep approximately constant the distance between plants (seeds) on the row, with very small deviations from the initial set distance.

MATERIAL AND METHOD

Analyzing the literature the following conclusions can be drawn about the factors influencing the accuracy of mechanized weeding plants seeding [1]:

- Position of the seed releasing point from the center of rotation;
- Distance between the seed releasing point and land, and its variation;
- Diameter of the holes layout on the distribution disk;
- Angular velocity variation of the element of distribution;
- Working speed and its variation;
- Shock and vibration of the hoe drill due to ground unevenness [2];
- The operator who, among others, shall maintain the direction of travel by means of markers;
- Physical and mechanical properties of seeds.

Depending on the type of culture, in order to obtain the calculated production per unit of area, its necessary to achieve a certain density, N [Pl / ha].

As the distance between rows of plants is D and between plants on the same row is d, sowing norm can be calculated by the relation:

$$N = \frac{10000}{D \cdot d} \text{ [Pl./ha]} \tag{1}$$

If D = ct., d = ct., then one would strictly realize the norm N after covering an area of 1 ha. In reality this is impossible because, the conditions under which D = ct, because of the constructive solution $d \neq$ct., because so far has not been made a distributor able to insert seeds at the same distance from one another in the same row. Therefore, within the analysis of the work process executed by hoe drills, deviations of ± 0.2 d are allowed, d being the theoretical distance between grains on the row. Seeding accuracy is:

$$P_d = \frac{n_o}{n_t} \cdot 100 \text{ [\%]} \tag{2}$$

where: n_0 is the number of distances between pockets on a row, at which the deviation from the theoretical distance d is ± 0.2 d; n_t - total considered number of distances between pockets.

From an agrotechnical point of view, seeding accuracy is good if $P_d \geq 80\%$. If we denote by v_m the speed of hoe drill in km/h, and by T the time between two successive seed releases [s], one can determine the theoretical distance between seeds on the same row with equation (3):

$$d = \frac{v_m \cdot t}{3,6} \text{ [m]} \tag{3}$$

Regarding the time between two successive releases where the speed of the distribution disk is known [rot/min], that speed is related to the center angle between two successive holes (α). Given that the angle covered in a second is $360 \cdot n/60$, or $6 \cdot n$ degrees/second, the angle α is covered in:

$$t = \frac{\alpha}{6 \cdot n} \text{ [s]} \tag{4}$$

The α angle is determined by the number of holes of the disk distribution:

$$\alpha = \frac{360}{n_o} \tag{5}$$

So, it results from equation (3):

$$d = \frac{v_m \frac{\alpha}{6 \cdot n}}{3,6} = \frac{v_m \cdot \alpha}{21,6 \cdot n} = \frac{360 \cdot v_m}{21,6 \cdot n \cdot n_o} \tag{6}$$

Relation (6) expresses the theoretical distance between two successive seeds from the same row also in case of seeds metering devices with fingers, where n_0 becomes the number of fingers, n is the speed of seeds metering device and v_m is the drill's speed.

Research showing the dependence of seeding accuracy on speed were performed worldwide. Illustrated here are tests results performed in 1994 at North Dakota State University. Tests were performed on three types of metering devices (with fingers, vacuum and air) at three different speeds (4.8 km/h, 8 km/h and 11.2 km/h). Figure 1 presents the results of these tests.

Working conditions were simulated on the stand in the following configurations: 205 mm between plants and 762 mm between rows, both for small seed and large seeds.

Tests were repeated 15 times for each type of metering device. As shown in Figure 1, the metering device with fingers performed the highest accuracy compared with those with vacuum and air.

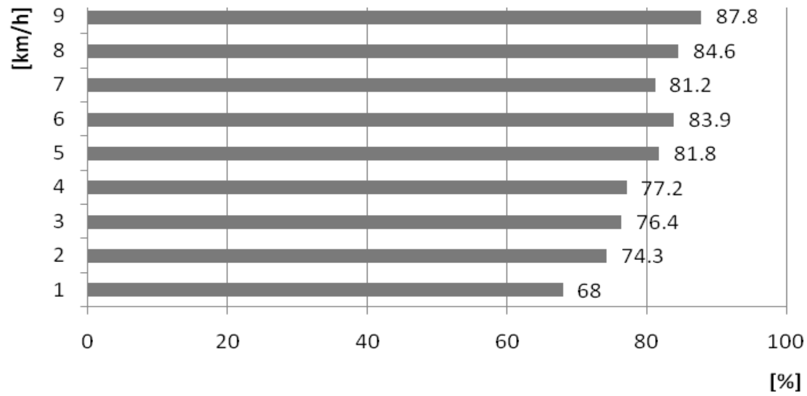

Fig. 1 Test results from North Dakota State University

EXPERIMENTAL RESULTS AND DISCUSSIONS

Experimental tests were performed in the Agricultural Machinery laboratory within the Faculty of Biotechnical Systems Engineering from „Politehnica" University of Bucharest. In the experimental test was used a pneumatic distributor with supply chamber, disk with holes, hollow chamber, fixed scraper and agitator inside de supply chamber mounted on the disk's drive shaft (Fig. 2).

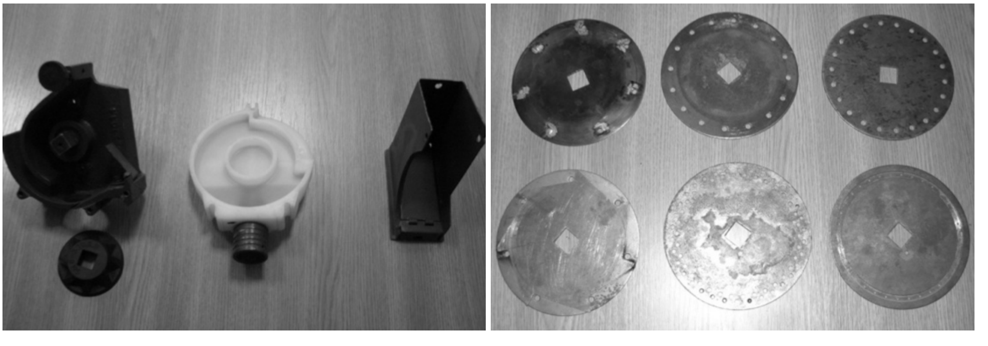

Fig. 2 Pneumatic metering device; supply chamber, hollow chamber, agitator; distribution disks

For tests was used the traditional method with conveyor speed with vaseline to simulate the working speed. Attempts were made for corn seeds (Turda 125l variety) and sunflower seeds (Fundulea 53 variety).

Experimental tests were carried out for various speeds of the working unit and different distances between seeds (different seeding norms). There were used seeding sections from SPC and SEMO Romanian hoe drills.

Figures 3 and 4 show the seeding accuracy depending on the speed of travel for the two hoe drills.

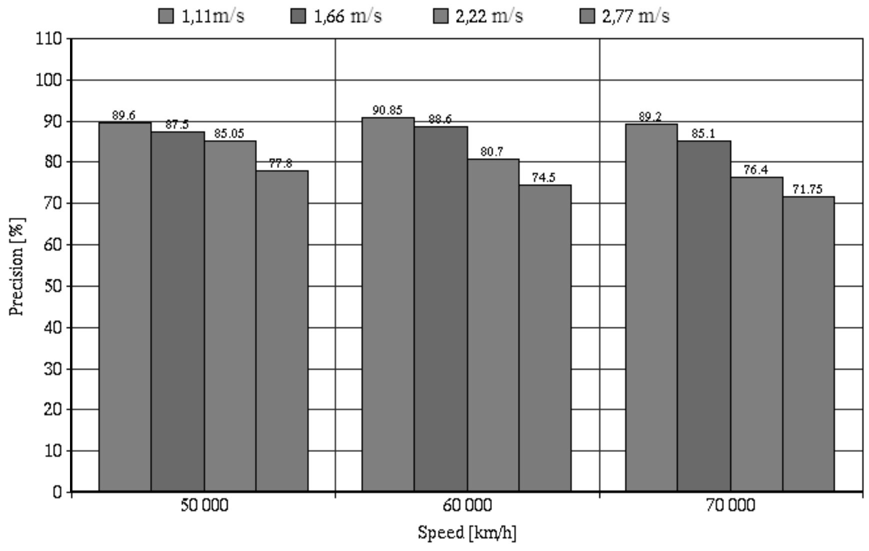

Fig. 3 Seeding accuracy depending on the speed of travel for SPC series hoe drill

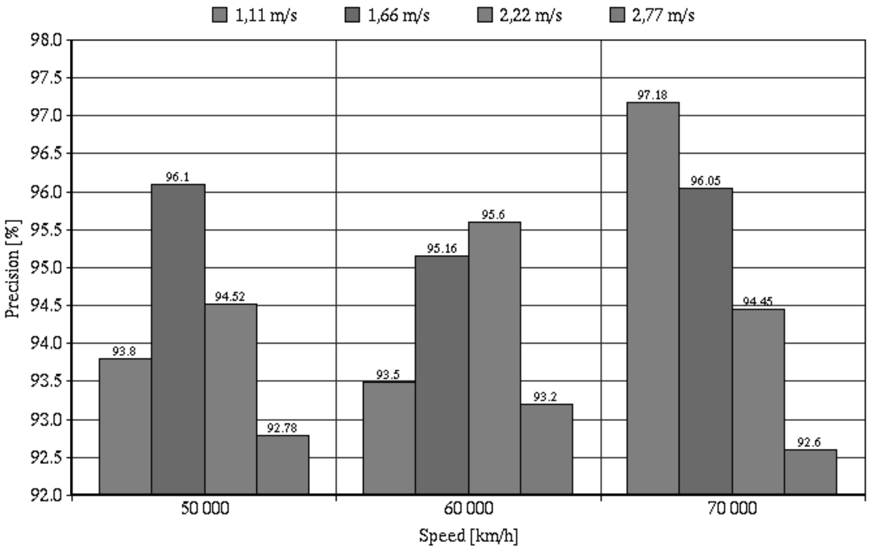

Fig. 4 Seeding accuracy depending on the speed of travel for SEMO series hoe drill

In the experimental tests there were used disks with different holes layout diameters. Experimental test results are plotted in Figures 5 and 6 for the two types of machines, for a norm of 60000 corn plants per hectare.

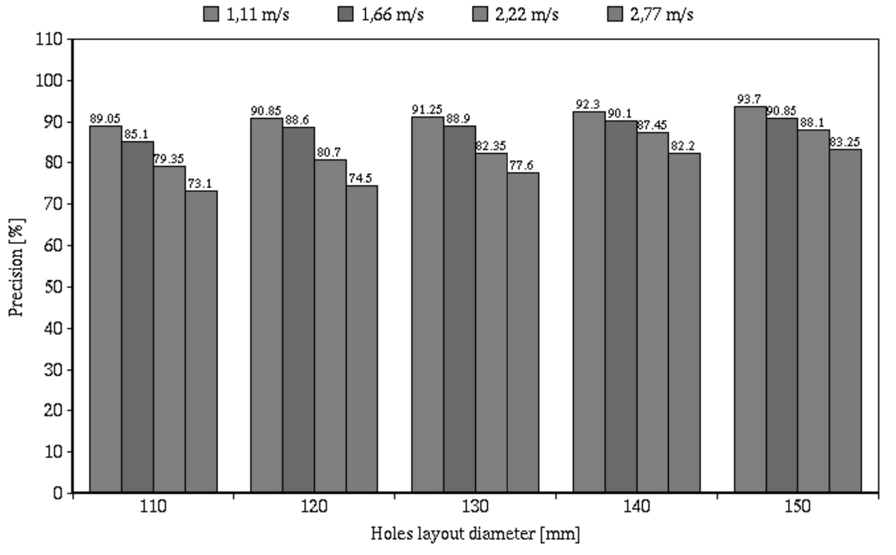

Fig. 5 Seeding precission vs. speed (different diameters of distribution disks; SPC drills)

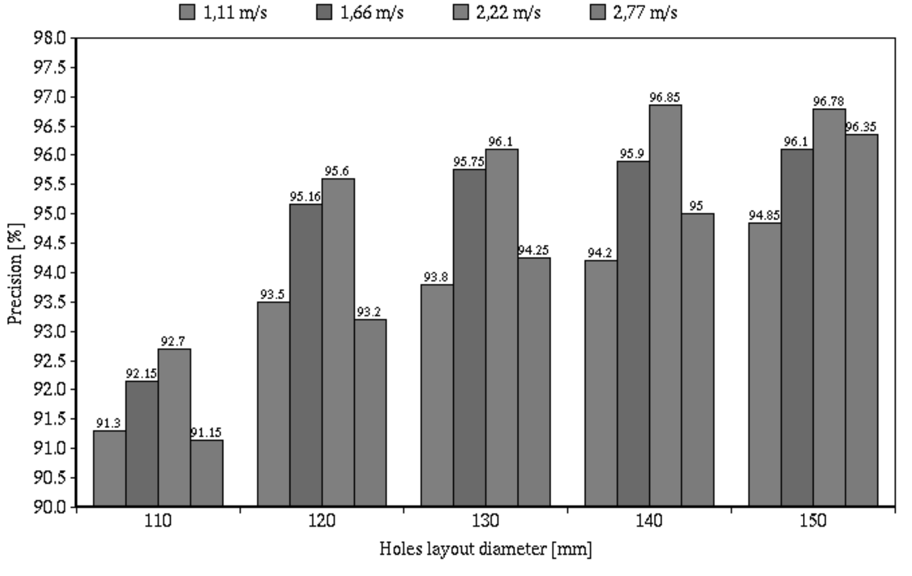

Fig. 6 Seeding precission vs. speed (different diameters of distribution disks;SEMO drills)

CONCLUSIONS

Analyzing the experimental results the following conclusions can be drawn:

- Working speed directly affects the seeding accuracy; it decreases with increasing work rate;
- Optimal speed for carrying out the seeding work is between 6 and 8 km/h;
- Seeding accuracy increases with increasing holes layout diameter on the distribution disk;
- Increasing the diameter is limited by the narrow space of the coulter, the place where seeding metering device is mounted.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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STUDY REGARDING CHOOSING THE OPTIMUM RHIZOME PLANTING EQUIPMENT

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SUMMARY

The energy requirements have grown significantly over the past years, thus it is necessary to choose alternative technology like renewable energy. This type of energy can be obtained by plant processing, wind energy, solar energy, etc. The most common one has become plant processing, like rape, miscanthus, energetic willow, corn stalks, straws, wood. The product can be obtained from using efficient planting and seeding equipment.

In agriculture, a series of equipments necessary for planting rhizomes are necessary and for choosing such equipment a comparative analysis of the main machines used in this field is also necessary. For achieving the main objective of this paper, we studied multiple types of planting machines, their working process, as well as the energy requirements, in order to determine the optimum equipment for obtaining a high production of miscanthus energy plant. During this part, we took their main characteristics into consideration and we used specific management methods.

The present paper is of real use for specialists in the field of construction and exploiting these agricultural equipments.

***Key words**: rhizome, miscanthus planter, characteristics, technical distance*

INTRODUCTION

Miscanthus is a perennial grass that is multiplied trough rhizome distribution. Bronze colored rhizomes have irregular shapes, their width being between 7-12 mm. For planting, young rhizomes are used (maximum three years old), healthy without wrinkles or mechanical damage, with length of 10-15cm and weight of 40-60g, having at least 3-4 viable buds. Planting distance varies with soils fertility [3]. On fertile soils stalks grow tall, and a distance of 100/100cm is recommended (10000 plants/ha), on medium fertile ground 50/100cm (15000 plants/ha), and for poor soils 50/50cm (20000plants/ha). Planting depth varies with planting time and soil nature, being of 8 cm on compact soils and 10cm on sandy soils. *Miscanthus* plant, as a renewable energy source produces a quantity of 15-20t/ha dry substance, has a perennial growth of 10-15 years, uses effectively nitrogen, water and other resources, is resistant to bacteria, hand for maintenance it requires a few fertilizers, pesticide and a few other chemicals.

Miscanthus stalks can be used as fuel for heat production, or for conversion into other products such as biogas, bio-ethanol or bio-diesel. There are constant preoccupations, both abroad and in Romania, for developing a planting process, optimal for rhizomes, in order to obtain a higher production.

In this purpose we can mention that from 2007, at the National Research Institute – Development for Machines and Installations for Agriculture and Foods Industry, researches were made regarding harvesting technology for *Miscanthus* and optimizing the planting process in order to obtain fuel, a process on which a number of teachers from Biotechnical Systems Department, from Polytechnic University of Bucharest. *Miscanthus* has a high capacity of exploiting soil fertility, as well as a high recycling capacity of important quantities of fertilizers through rhizomes.

Mature rhizomes keep more fertilizer than the plants need, so that after two life cycles, fewer quantities of fertilizer are needed. For exploitation, according to initial soil furnishing, 25 kg/ha P_2O_5, 50...60 kg/ha K_2O and 150 kg/ha N are needed.

Although multiple *Miscanthus* planting equipments are built, there are, however, few things known about these machines, and the specialty literature doesn't say which machine is the best. Choosing the right machine and estimating its performance must be done taking in consideration the soil type, climatic conditions, harvested surface and the required productivity.

Miscanthus rhizomes plantation is done with special equipment, by technologies developed in Denmark, but also in other states of EU or America. Plantation method was increasingly developed, first by researchers in Great Britain, than in other countries, and today it is under the surveillance of International Energy Crops. What must be remembered is that in that parallel to the energetic willow, *Miscanthus* crop maintenance is done with conventional equipment used in day to day agriculture. [4].

Starting a *Miscanthus* crop must begin a year before plantation, so that the necessary processes will take place in time, where the terrain is likely to erode. Any activity of this kind, after rhizome planting creates a high risk of spreading the plant outside the crop. The plant is very sensible to competition with neighbor plants, a fact that implies adequate control over the crop.Weeds must be eliminated through herbicides both pre-emergent, and also post-emergent [10]. In order to obtain a *Miscanthus* crop with corresponding density of plants, rhizome selection, quality and age, storage duration, planting technique and maintenance. Rhizomes must have the capacity to develop and divide into air layers for future plants [1, 9].

RHIZOME PLANTING MACHINES CONSTRUCTION

Rhizome planting machines with distribution apparatus with manual alimentation mechanically execute all operations from the process of planting, minus feeding the rhizomes to the distributors, which is done manually [2]. Distribution apparatus more common are the ones equipped with compartmented horizontal drum type distributors. A rhizome planting machine with manual feed equipped with such apparatus has a number of sections, with articulations to the machine, rhizome bunkers, markers and transmission. On the frame of each section the distribution apparatus is mounted, rhizome guiding tube, share, covering organs and the worker's chair for feeding the distributor. The distributor of such apparatus is represented by a cylindrical body, horizontally paced, having a number of compartments, their mobile base being represented by clacks, articulated to the body. Under the distributor a guiding bar is mounted that holds the clacks which close the compartments at the lower side. In front of the rhizome guiding tube, the guiding bar presents a gap which liberates the clack that holds the rhizome and it is let go in the share's channel.

Types of shares that can be used for rhizome planting machines:

A) **Anchor type share** with a pointy tip, are separated into heel share and heelless share. Heel share have a stable work rate in depth. They are used on easily processing soil. Heelless shares have a less stable working rate and are used on heavy soils, where a heel share doesn't penetrate [8]. For optimal production, rhizome planting must be made in proper conditions. During the paper, we analyzed four types of rhizomes planting machines, already used in Romania and abroad, for identifying the maximum productivity machine that corresponds technically.

B) **Disc shares** can be realized from a disc or two that ensures a more uniform seeding depth. Disc diameter is of 350+0,6mm. The angle between the discs can be of 10°.

Planting machine *Miscanthus* MPM-4 [11] works in aggregate with 65HP tractors with their wheels equipped with hydraulic lifters, category 2, according to SR ISO 730-1+C1. This machine is used inside the crop technology for *Miscanthus*. The main technical characteristics of this machine are presented in table 1.

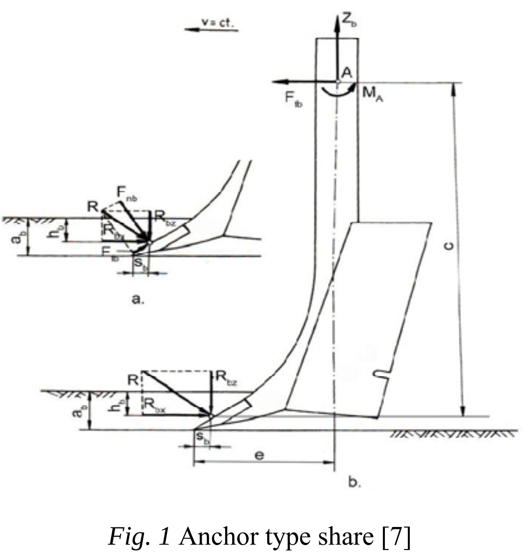

Fig. 1 Anchor type share [7]

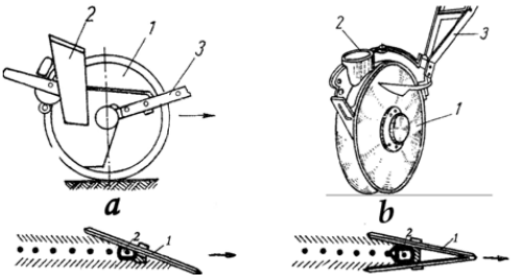

Fig. 2 Disc shares; a) share with mono disc, b) share with double disc [6]

Fig. 3 Planting machine *Miscanthus* MPM-4 [11]

The *Miscanthus* planting machine (fig.2) is composed out of: machine frame, planting section group. Left/right markers, covering wheels placed in V (left/right); print marker action device and two transport wheels.

For moving the car, the section share (guide) opens the channel where the rhizomes will be placed, by operators, through an oval tube. Soil that is spread by the guide is covering the rhizomes and is pressed over by two metallic wheels in a V shape, leading to correspondent germination conditions.

In the working process, the machines realizes the channel opening to the share, the operator introducing a rhizome at a time inside the channel through the guiding tube, from there covering it with soil and pressing over the rhizomes by the wheels placed in the lower part of the section.

Semi-automated *miscanthus* planting machine [12], working in aggregate with 48 kW tractors with hydraulic lifters. For maximum production rate, the planting depth must be of 5-8 cm. Ideal planting period is in March or April. This machine is used during the technology for starting a *Miscanthus* culture.


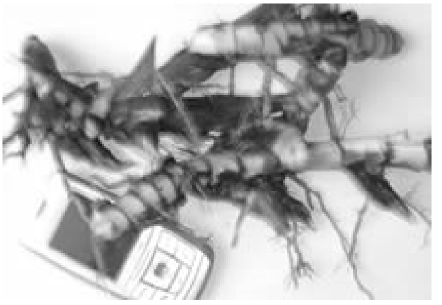

Fig. 4 Semi-automated *miscanthus* planting machine [12]

Semi-automated *Miscanthus* planting machine is composed out of: machine frame, planting sections, rhizome box, left/right markers, compaction wheels, marker action device.

The *Miscanthus* planting machine adapted from the potato planting machines [13], works in aggregate with 110 kW tractors on wheels with hydraulic lifters. Soil must be worked until a maximum depth of 10-15cm before planting. Rhizomes are planted at a depth of 8-10 cm. For an optimal growth a fast process is necessary. Soil preparation for *Miscanthus* planting must be made like in the case of corn crops, autumn furrow and the terrain is prepared with a)-chisel (scarifier) or a tormentor immediately after the soil gets dry in the spring. The soil must be worked until a maximum depth of 10-15 cm before planting.

Technical equipment with working organs for rhizome planting, works in aggregate with 150HP tractors on wheels with hydraulic lifters category 3 according to SR ISO 739-1+C1. The machine has nine planting sections and manual distribution of rhizomes in the channel. Covering the channel is made by two curved metallic discs.


Fig. 6 The *Miscanthus* planting machine adapted from the potato planting machines [13]

The NORDIC planting machine [5] (Hvidsted Energy Forest) High-capacity and automatic machines - which are suitable for rhyzome planting - need special production, expensive and hard to be set. Revolver type of potato planters is suitable for this purpose but only in the case of 10 cm or smaller rhyzome units. Manual potato planter machines have low-capacity and in the same time could plant various sizes and shapes of rhyzomes.

In this case the only problem is that the workers have to be constantly pay attention for the signal of clicking device and it is tiring. So that development of a mechanical feed rhyzome planter with manual serving is recommended. This construction claims less concentration from workers because they could feed the device in their own speed with feeding more units at the same time.

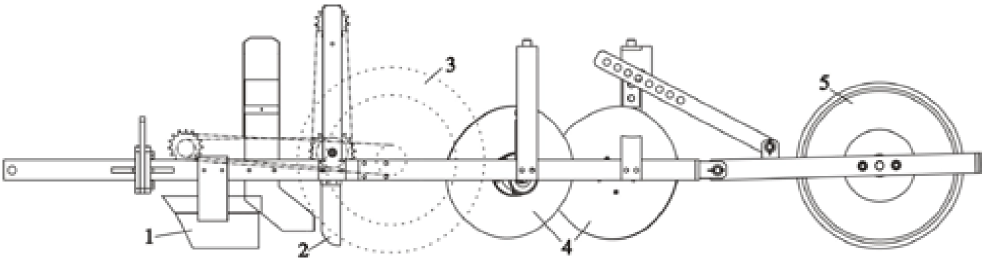

Fig. 7 NORDIC rhizome planting machine design [5]; 1. Channel opener share; chain cup distribution apparatus; 3. Transport wheels; 4. Covering metallic discs; 5. Compaction wheels.

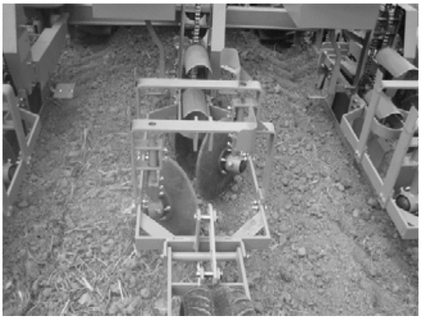

Fig. 8 NORDIC rhizome planting machine design [5]

MATERIALS AND METHODS

In order to analyze technical characteristics of rhizome planting machines and comparing them on the basis of characteristics, the paper assumes the use of technical distance method toward an ideal equipment. Ideal equipment is a fictive equipment to which all groups and subgroups have the highest degree of competitiveness, according to worldwide levels, it has the highest technical characteristics of all analyzed equipments.

DISTEH method permits quantifying the technical level of analyzed equipment groups, comparable between each other, through technical distance toward ideal equipment calculus, outlining the action directions in research-design-fabrication activities, but also in picking the right device, according to economic unit conditions. This method permits comparing the analyzed equipments, according to a total unit in their exploitation, as well as comparing different criteria, according to technical level improvement speed, so it can indicate which groups, subgroups or organs must be perfected in order to perfect its competitiveness. In this paper only equipment analysis and comparing them towards the ideal equipment is used, comparing between each other four *Miscanthus* rhizome planting machines (M1- MPM-4 planting machine, M2- Semi-automated planting machine, M3- Planting machine adapted from potato planting machines, M4- Nordic planting machine). Technical characteristics of analyzed machines are presented in table 1, these having the indicator M_i ($i \in (1,4)$), while the technical characteristics having the ($j \in ((1,7)$) indicator.

For qualitative technical characteristics comparison, a coefficient of 0.5 was considered for the rhizome covering module with the metallic wheels, 1 for the rhizome covering module with metallic discs, and 0 for covering the channels with fixed blades.

RESULTS AND DISCUSSION

Technical characteristics of the ideal planting machines are either the maximum values of the other planting machines, if that characteristic represents a maximum criteria, either the smaller value of the technical characteristics taken into study, if that characteristic represents a minimum criteria. Technical characteristics from Table 1 are appreciated according to score (given 0 and 1), through comparison between planting machines taken into study.

Table 1 Analyzed rhizome machine planting technical caracteristics

	Characteristic	M1	M2	M3	M4	M ideal
C1	Tractor power, kW	48	48	100	74	48
C2	Working width,m	3.4	3.6	4.5	4	4.5
C3	Working depth, cm	8.5	6.5	9	9	6.5
C4	Number of planted rows	4	4	9	4	9
C5	Machine mass, kg	610	580	1025	880	580
C6	Distance between rows, m	0.85	0.90	0.50	1.0	0.85
C7	Rhizome covering mode	Metallic wheels în V (0.5)	Fixed blades (0)	Metallic discs (1)	Metallic discs (1)	Metallic discs

Following the analysis of the main technical characteristics of the rhizome planting machines through DISTEH method, the effective balances are presented in table 2. In accordance with their importance in exploitation, it was considered that C1 parameters (necessary action power) and C2 (machine working width) have the same balance and are preferred before the other characteristics. Also, C3 parameters (working depth) and C4 (number of planted rows) are equivalent, but are preferred before C5 parameters (machine mass), C6 (distance between rows) and C7 (rhizome covering model).

(C1 *I* C2) *P* (C3 *I* C4)
(C3 *I* C4) *P* (C5 *I* C6 *I* C7)
(C1 *I* C2) *PP* (C5 *I* C6 *I* C7)

The importance coefficient calculus is done, according to DISTEH method algorithm, through comparing each C_j criteria, with each other (n-1=6) criteria, according to their importance in exploitation.

Table 2 The corelation table between the DISTEH parameters used for the analysis

	C1	C2	C3	C4	C5	C6	C7	$\sum a_j$
C1		1	2	2	4	4	4	17
C2	1		2	2	4	4	4	17
C3	0	0		1	2	2	2	7
C4	0	0	1		2	2	2	7
C5	0	0	0	0		1	1	2
C6	0	0	0	0	1		1	2
C7	0	0	0	0	1	1		2
								$\sum a_{j1} a_{j2} = 54$

γ_j balances given to analyzed technical characteristics, according to their importance in exploitation, calculated according to the presented methodology are:

$$\begin{gathered}\gamma_1 = \gamma_2 = 17 / 54 = 0.3148 \\ \gamma_3 = \gamma_4 = 7 / 54 = 0.01296 \\ \gamma_5 = \gamma_6 = \gamma_7 = 2 / 54 = 0.037\end{gathered} \tag{1}$$

Through technical distance calculus of a machine towards the ideal machine we used the relation:

$$T_i = d(M_i, M_I) = \sqrt{\sum_{j=1}^{n} \left(\frac{C_{ij} - C_{Ij}}{C_{Ij}} \right)^2} \tag{2}$$

Following that stage, we could estimate which technical characteristic of a certain machine must be perfected, so that the overall performance will grow, through shrinking the technical distance towards the ideal machine.

Aplying the {2} relation, in which M_i represents the I machine, from the four analyzed, and M_j, the ideal machine, C_{jj} the “j” characteristic of the “i” analyzed machine, and C_{Ij} the “j” characteristic of the “I” ideal machine, the values of the technical distance for all the four planting machines, towards the ideal machine (to which all authors have assumed the minimum and maximum characteristics).

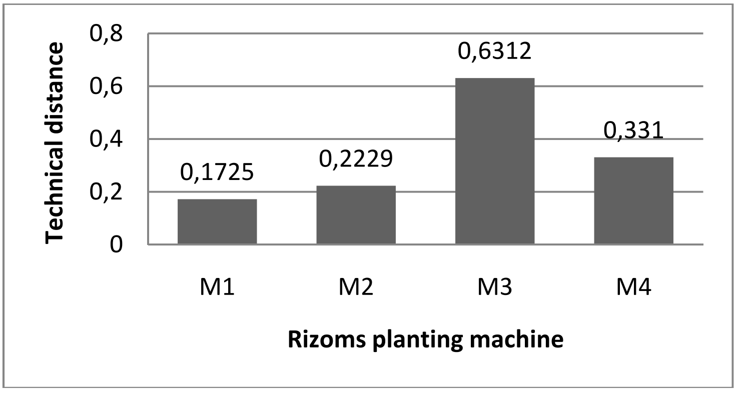

Fig. 9 The distribution of the technical distance for the four planting machines

CONCLUSIONS

Miscanthus rhizome planting machines are constructed from a vast array, taking in consideration both the constructer, as well as the financial possibilities of the farms that harvest this plant. On the other hand, these machines differ between each other by share type, by the type of distribution and rhizome leading apparatus to the channel, by the channel covering system, as well as by the soil compaction system over the planted rhizomes.

So, the *Miscanthus* rhizjome planting machine section shares can be guide type, with different opening angles for the two sides, and with different attack angles, or metallic disc types, straight or curved, inclined towards the machine travel direction, but also towards the perpendicular plan one the travel direction, having one or two discs. Distribution apparatus types are also different, according to the mechanization type and planting operation automation.

Covering the channels in which rhizomes have been placed can be made by fixed covering blades, inclined towards the forward speed or with v shaped metallic wheels, or without bulges, but also with curved metallic discs placed inclined towards the vertical, existing with decaled placing, so that the working process of a disk will not be influenced by the other. Channel compaction can be made by metallic wheels, with straight blades, fixed or with tyre wheels, as we find in the most common cases.

For the rhizome planting machines analyzed during this paper we considered that the closest to the ideal machine was the M3 machine (*Miscanthus* planting machine adapted from the potato planting machines), because according to the analysis of the four types of rhizome planting machines, this was the closest to the ideal rhizome planting machines.

AKNOWLEGEMENT

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

LEAF SURFACE COVERAGE AND NOZZLE CHARACTERISTICS OF THE FILED SPRAYER IN DEPENDENCE OF ITS WORKING PRESURE, APPLICATION RATE AND WORKING SPEED

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SUMMARY

In order to have a good visual inspection of the foliage surface coverage quality after the use of filed sprayer, water-sensible papers can be used. Surface coverage, droplet distribution and solution incorporation into the plant canopy beside the sprayer itself, depend on the plant canopy characteristics (number of trees, their development stage, shape of the foliage), weather conditions during the application etc.

The aim of this paper was to give the results of testing the three nozzle types (standard, anti-drift and injection) in the different working regimes of the filed sprayer in order to obtain the optimal foliage surface coverage. With the use of currently available filed sprayers, the application rate can't be lower than 200 l/ha. Sprayers with the air induction nozzles have a significant advantage concerning the fact that they can operate in windy conditions (8 m/s) with the operating pressure of 8 bar but they are still not universal for all working conditions.

***Key words**: nozzle type, working speed, application rate, working pressure, surface coverage*

INTRODUCTION

One of the main tasks of the agricultural sprayers is to have a good leaf surface coverage with the minimal spray losses. This is the reason why great attention is given to the nozzles and specially the air-assisted ones.

The standard nozzles have the XR (Teejet) and LU (Lechler) labels. The anti-drift nozzles are labeled with the AD (Teejet) and DG (Teejet) labels. The common characteristic of these nozzles is they have a lower share of small drops and thus a smaller loses by drift. Further improvement can be made with the usage of the TD (Agrotop) and ID (Lechler) nozzles. The best characteristics were observed for the AI (Teejet) and TD-XL nozzles with the air induction. There are some nozzles with the coarse spray such as TT (Teejet) without air induction but these are used for the herbicide application.

Introduction of the air induced nozzles lead to the improved quality of application and reduction of the spray drift by 75% compared to the standard (XR; LU) and anti-drift (AD; DG) nozzles. These nozzles can work with the wide range of working pressure (2-8 bar) not influencing the droplet size spectra significantly. Porskamp et al, (1995) and Southcombe et al. (1997) stated that there was up to 50% lower quantity of spraying fluid on the ground if these air-assisted nozzles were used. They also stated that the drift at the range of 2.25 m from target surface was 70% lower. Van de Zande et al (2000b) confirmed that, with the usage of air induction nozzles drift can be lowered up to 70% compared to the classical (XR) and anti-drift (DG) nozzles.

When using strip technology in the corn and sugar beet plant protection quality of application depends on the distance between rows and plant development stadium (Van Zuydam et al, 1996, Van de Zande et al, 1996, Van de Zande et al, 2000e). Similar problems were stated for the orchards and nurseries by Porskamp et al (1994a; 1999a) and Huijsmans et al (1993, 1997). Stalling et al. (1999) stated that the amount of the spraying liquid that reaches the soil surface, in the case of cereal production, depends on the plants height.

De Jong et al (2000a, 2000b) studied the influence of the different nozzle position to the target area on quality of deposition. They used conational and air-assisted sprayers on the 2-3 m distance from the crops. The nozzles were 30, 50 and 70 cm above the crops. They stated that this distance from the target area had more significant influence in the case of conventional sprayers while in the case of air-assisted sprayers these differences did not have a significant influence on the sprayer deposit on the crops.

Using the edge OC nozzles (Teejet) at the end of the boom section can lower the spray drift by 20% and 60% respectively compared to the anti-drift and air induction nozzles. At the 1-2 m target area distance the spray drift was lower 50 to 80% (Van de Zande et al 2000d). However it can be stated that there are no universal nozzles for all the crop species and all the weather conditions (Bugarin et al, 2003, Urošević et al, 2006). The nozzle selection must be adjusted to the specific conditions of application.

MATERIAL AND METHOD

During the 2009., field experiments were carried with the aim of investing the three different types of nozzles (standard, anti-drift and air induction). For the purpose of investigation standard and air-assisted (2.000 m^3/h) sprayers were used and their operating pressure and working speed were varied. Water-sensible paper, 52 x 76 mm, was used for the obtaining the pattern of the spraying liquid. The papers were placed on the wooden supports close to the soil surface at the 20 m distance.

Before starting of the experiment the manometer was tested using the AAMS testing equipment (Fig. 1). During the experiment climatic conditions were measured 2 m above the ground using the Kestrel 4000 hand meter (Fig. 1). Average temperature was 18 ºC, air relative humidity 58 % and wind speed below 2 m/s. The spray pattern and the coverage of the water-sensitive papers were analyzed with the Doppler Particle Analyzer.

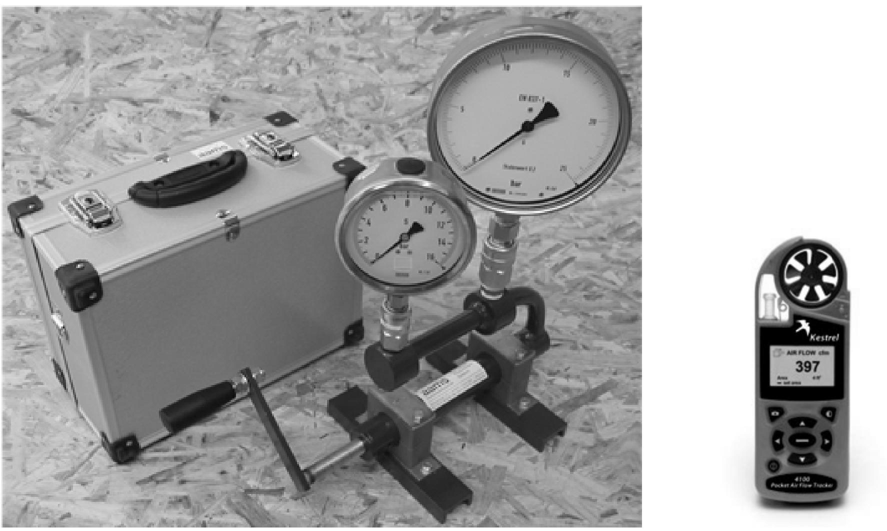


Fig. 1 Manometer tester and Kestrel meter

RESULTS AND DISCUSSION

Working pressure

Figures 2 and 3 show the water marks of the spraying liquid obtained by the standard nozzle LU 120-04 under the conditions of 300 l/ha application rate and by the induction nozzle IDK 120-04 under the conditions of 300 l/ha application rate. If analyzed, it can be seen that the coverage pattern and the droplet size distribution depend on the working pressure. Under the same application rate and same pressures but with the speed variation it can be seen that the spray pattern of the standard nozzles are more susceptible to variations.

With these nozzles, if working pressure is increased the share of smaller droplets susceptible to drift, is also increased.

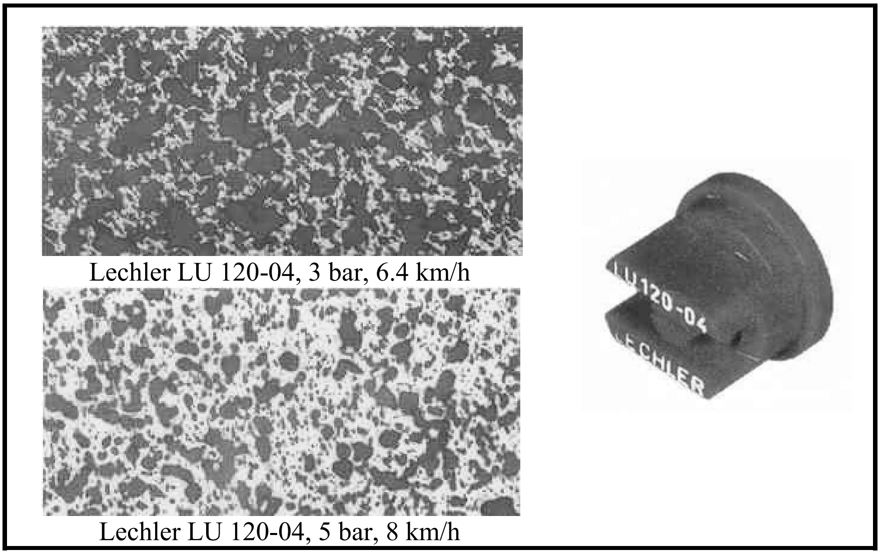


Fig. 2 Water-marks obtained by the standard LU 120-04 nozzle with the 300 l/ha application rate

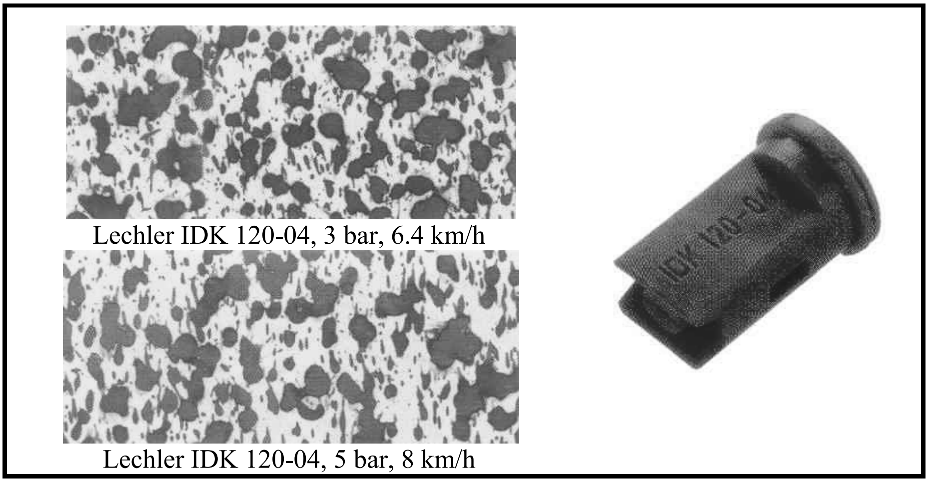


Fig. 3 Water-marks obtained by the air induction IDK 120-04 nozzle with the 300 l/ha application rate

When there was a 1 bar reduction in the working pressure standard nozzles were leaving the more uniform pattern compared to the air induced IDK 120-04 nozzles. This indicates that more care must be taken when adjusting working pressure for IDK nozzles. Pressure of 1 bar is obviously not enough for the proper leaf coverage (Fig. 4) and it also causes the higher share of larger droplets that leads to the lower efficiency of the spraying liquid.

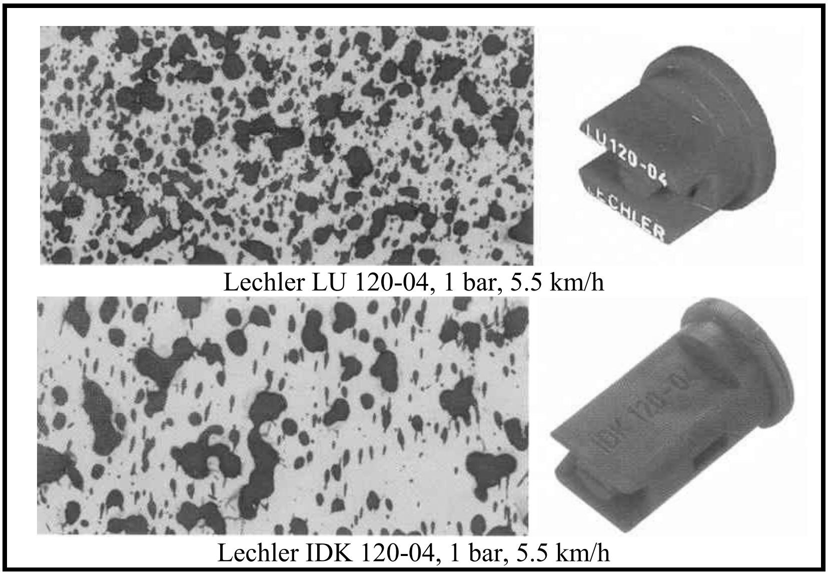


Fig. 4 Water-marks obtained by the standard and air induction nozzles with the 200 l/ha application rate

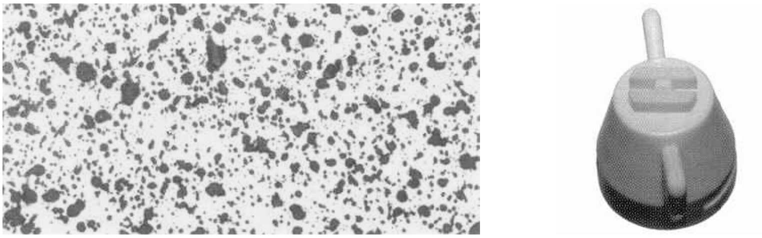
Working speed and operating pressure

The influence of the working speed and operating pressure on the working properties of the air induction nozzle is presented in the Figure 3. If water-sensible paper is analyzed it can be seen that the better uniformity of distribution and area coverage was achieved in conditions of 6.4 km/h working speed and 3 bar operating pressure.

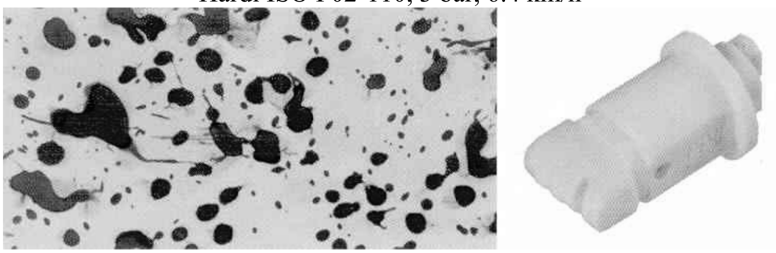
Air induction nozzles produce coarser spray that has a higher speed thus it is less susceptible to drift. If the operating pressure is increased to 5 bar and working speed to 8 km/h the more intensive vertical and horizontal oscillations were observed on the boom section that had lead to the more intensive drift.

Spraying quantity

It is a well know fact that better coverage of the target area can be achieved by the increasing of the application rate. When standard ISO F 02-110 and air induction TTI 110-02 nozzles were used it was observed that induction nozzles had poorer coverage compared to the standard ones (Fig. 5). Concerning the lower application rate and poorer coverage the applied treatment will not have and adequate biological effects.

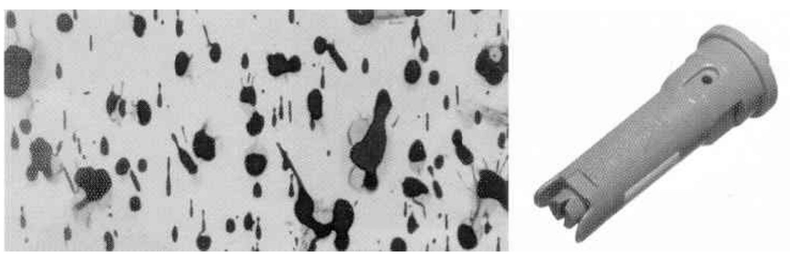


Hardi ISO F02-110, 3 bar, 6.4 km/h

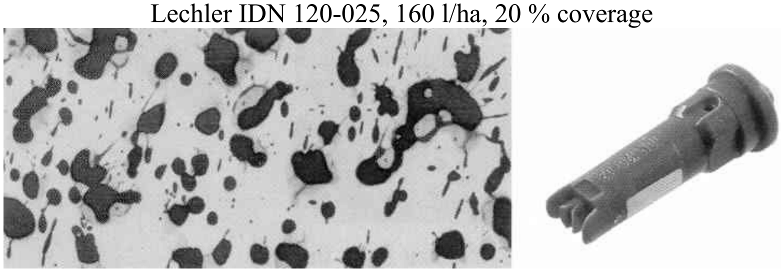


TeeJet TTI 110-02, 3 bar, 6.4 km/h

Fig. 5 Water-marks obtained by the standard and the air induction nozzles with the 150 l/ha application rate



Lechler IDN 120-025, 160 l/ha, 20 % coverage

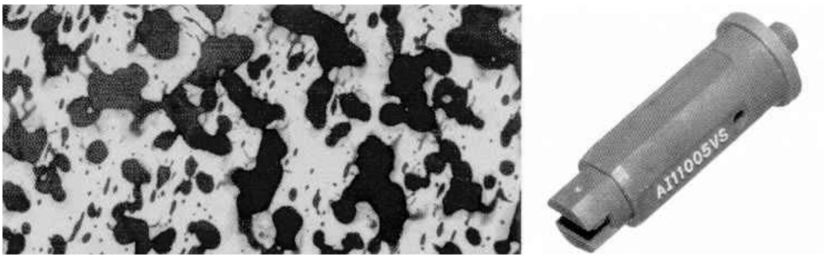


Lechler IDN 120-03, 200 l/ha, 30 % coverage

Fig. 6 Water-marks obtained by the IDN nozzles under 2 bar operating pressure and 6 km/h working speed

The combination of low pressure and low speed often cannot give the adequate target area coverage. Large droplets and lower application rate result in poor leaf coverage. In order to achieve better coverage and uniformity when using the long air induction nozzles (IDN) higher application rates should be used (≥ 250 l/ha). This application rate should be reached under the 2 bar operation pressure and lowered working speed.

The air induction nozzles with the wider opening (AI 110-05) achieve the application rate of 330 l/ha at the 2 bar working pressure and 6 km/h working speed, and are considered to be efficient in the chemical protection in potato. These nozzles are considered very efficient because they have a large wetting area (Fig. 7) and, thus, better biological effects on the target areas.



TeeJet AI 110-05, 330 l/ha, 46 % coverage

Fig. 7 Water-marks obtained by the air induction nozzle under the 2 bar operating pressure and 6 km/h working speed

Air assistance

It was observed that in the conditions of 3 bar operating pressure and 6.4 km/h working speed, if common and air induction nozzles were used (Fig. 8) coverage of the leaves inside the plant canopy was better. The used nozzles were ISO F 02-110 (150 l/ha) and ISO F 04-110 (300 l/ha). If the nozzles with wider openings are used (for example 04) the effect of the air assisting technology is less noticeable. Droplets larger in diameter have a higher mass and thus have a stable trajectory to the target area. One of the effects that is also present in the case of air –assisted technology is the joining (networking) of the drops that leads to the spray leakage.

Air assistance and quantity of the applied liquid

Figure 8 shows spray pattern for the standard and air induction nozzles with and without air assistance under the 3 bar operating pressure, 6.4 working speed and 150 and 300 l/ha application rate.

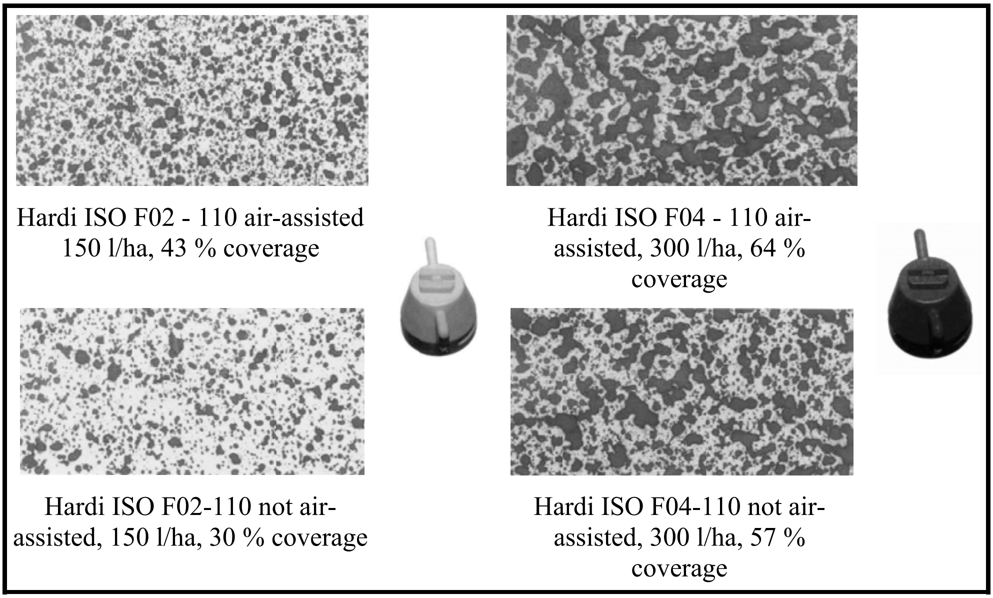


Fig. 8 Water-marks obtained by the standard and air induction nozzles with or without air assistance under 3 bar operation pressure and 6.4 km/h working speed

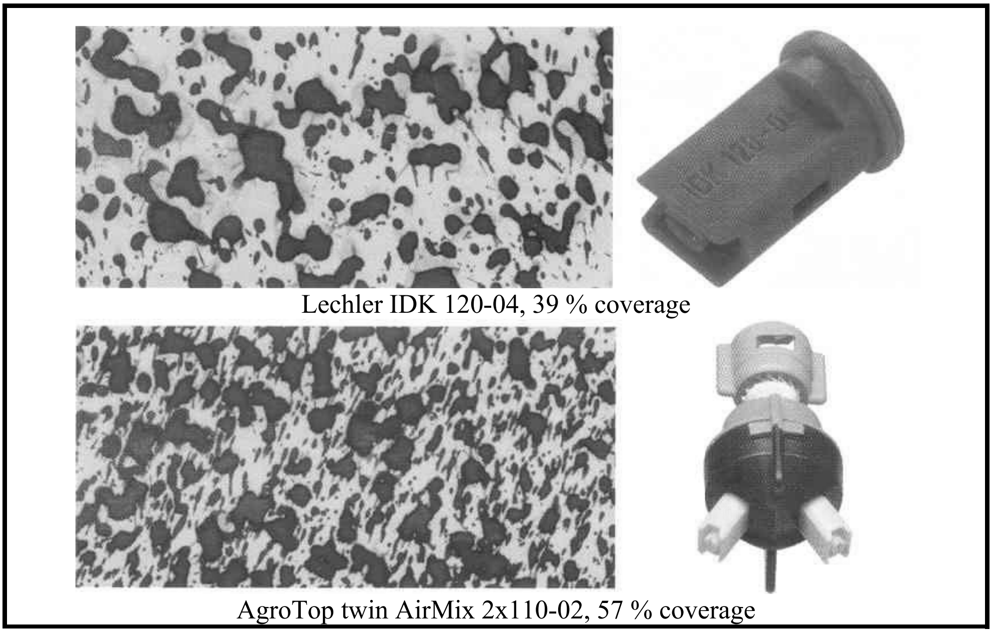


Fig. 9 Water-marks obtained by the IDK 120-04 and AirMix 2x110-02 nozzle (300 l/ha, 3 bar, 6.4 km/h)

If the patterns are analyzed it can be concluded that better coverage was obtained with the nozzles that had the air assistance. It was expected to have a higher number of droplets in the case of air assistance. At the same time in the droplet spectra of the air-assisted nozzles the share of smaller droplets was higher. Concerning these and the fact that with the air-assistance the spray direction can be changed, there is a certain advantage of the air assisted nozzles.

Spray angle: Figure 9 shows the water deposit patterns obtained by the IDK 120-04 and AirMix 2x110-02 (TwinJet) nozzles under the conditions of 3 bar working pressure, 6.4 km/h working speed and 300 l/ha application rate.

If the pictures are analyzed it can be concluded that better coverage can be achieved with the use of twin jet nozzles. This can be explained by the nozzle diameter and spay angle. When nozzle opening was 02 the higher number of small droplets was produced compared to the 04 opening. In case of TwinJet nozzles spraying angle of 30^0 enabled the spraying deposition in the upper parts of plants and on both sides of the target area. Combining these two it was possible to obtain the better coverage.

CONCLUSIONS

Standard nozzles have a high share of small droplets in the spectra that can lead to the intensive drift and, thus, loss of spraying liquid and poor effect in chemical plant protection. Higher working pressure and higher speed have the same consequences.

Air induction nozzles generate spray richer in larger droplets that are not susceptible to drift and have stable trajectory. When used with the application rate of 200 l/ha these nozzles do not give satisfactory results in the sense of target surface coverage. Thus, an application rate of 250 l/ha can be recommended. Good coverage can be achieved if the air induced nozzles are used with the smaller opening enabling the higher number of droplets that are reaching the target area thanks to the air assistance. The twin nozzles can find a good application in the conditions of dense filed crops due to their good spray deposition to the target area.

ACKNOWLEDGEMENT

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.34(497.5)
Stručni rad
Expert paper

TESTIRANJE TEHNIČKIH SUSTAVA U ZAŠTITI BILJA U REPUBLICI HRVATSKOJ

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SAŽETAK

U cilju prilagodbe hrvatskih obiteljskih poljoprivrednih gospodarstava na novo zakonodavstvo Europske unije, obavljena su predavanja i testiranja tehničkih sustava u zaštiti bilja financirana sredstvima Nizozemske darovnice (TF070378), koju su proveli djelatnici Zavoda za mehanizaciju Poljoprivrednog fakulteta u Osijeku. U programu sudjeluje 17 poljoprivrednih udruga sa prostora Slavonije i Baranje. Cilj ovih predavanja bio je obučiti rukovatelje tehničkih sustava u zaštiti bilja za rad sa istim te testirati njihove strojeve i ukazati im na greške koje se trebaju ispraviti. U EU je na snazi direktiva 2009/128/EC i 2006/42/EC kojima je temelj EN 13790 (I,II) standard za testiranje tehničkih sustava u zaštiti bilja. Ulaskom Hrvatske u EU ove direktive postaju aktualne te im se polako treba pridavati značaja.

Ključne riječi*: tehnički sustavi u zaštiti bilja, rukovatelji, testiranje, EN 13790 standard*

UVOD

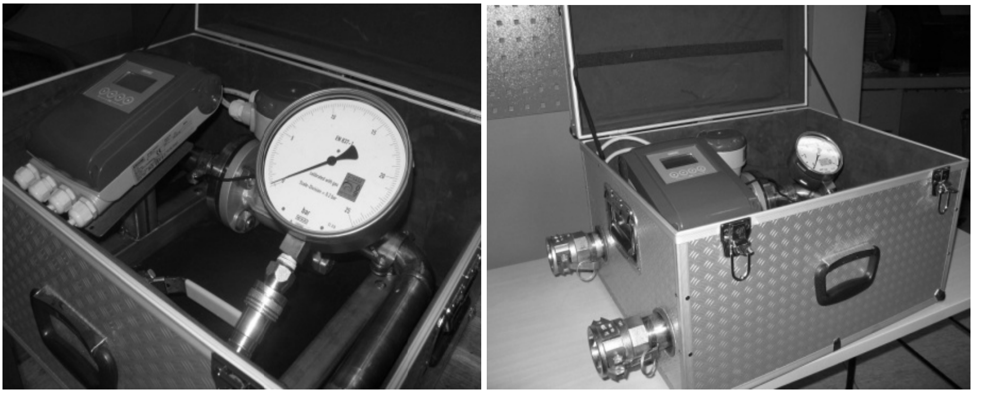
Testiranja tehničkih sustava u zaštiti bilja u Europskoj uniji počela su krajem devedesetih godina prošlog stoljeća te su testiranja pokazala koji su dijelovi prskalice najpodložniji kvarovima. U Njemačkoj testiranja su pokazala da je najveći broj neispravnih prskalica uzrokovan neispravnim mlaznicama. Od preko 70000 testiranih prskalica, kod 19% utvrđene su neispravne mlaznice (Reitz i Gamzlemeier, 1998). U Belgiji u razdoblju od 1995. do 1998. godine testirano je 17 466 prskalica od kojih 86% je bilo neispravno zbog neispravnih manometara i mlaznica (Langenakens i Pieters, 1999). Ozbiljnija testiranje tehničkih sustava u Republici Hrvatskoj krenula se krajem prošlog desetljeća i već onda su zabilježeni loši rezultati površinske raspodjele tekućine pri radu ratarskih prskalica (Banaj i sur., 2000). Najvažniji čimbenik cjelokupnog stroja za zaštitu bilja predstavlja mlaznice te ona obavlja najvažnije funkcije propuštanja zadane količine tekućine u jedinici vremena, raspršuje tekućinu tvoreći kapljice odgovarajućih veličina te formiraju mlaz odgovarajućeg oblika (Banaj i sur., 2010). Veliki problem stvaraju potrošene i začepljene mlaznice koje daju veće ili manje količine protoka, pa je potrebno da se neispravna mlaznica zamijeni (Bugarin i sur., 2000).

MATERIJAL I METODE RADA

Krajem 2011. godine Zavod za mehanizaciju Poljoprivrednog fakulteta u Osijeku krenuo je u provedbu projekta testiranja tehničkih sustava u zaštiti bilja u pet županija istočne Hrvatske prema projektu financiranom iz sredstava Nizozemske darovnice (TF070378). U daljnjem tekstu prikazani su rezultati testiranja 92 stroja u 5 testnih mjesta. Za provedbu testiranja korištena je oprema Zavoda za mehanizaciju, Poljoprivrednog fakulteta u Osijeku. Zavod posjeduje svu potrebnu opremu za provedbu testiranja tehničkih sustava u zaštiti bilja po normi *EN 13790* koja je osnova za provedbu direktiva *2009/128/EC i 2006/42/EC* Europske unije. Mjerenje kapaciteta crpke obavljeno je pomoću elektromagnetskog mjerača protoka tvrtke *Krohne* (Slika 1.), dok je ispravnost manometra utvrđivana pomoću komparatora tlaka *Volos* (Slika 2.). Mjerenje protoka mlaznica na raspršivaču provedeno je s uređajem domaće izrade (Slika 3.) te s elektronskim mjeračem protoka tvrtke *AAMS* (Slika 3.). Zavod za mehanizaciju također posjede uređaj s*pray scanner* tvrtke *AAMS* (Slika 4.) koji je primijenjen za utvrđivanje površinske raspodijele tekućine pri radu ratarskih prskalica.

Kontrola kapaciteta crpke

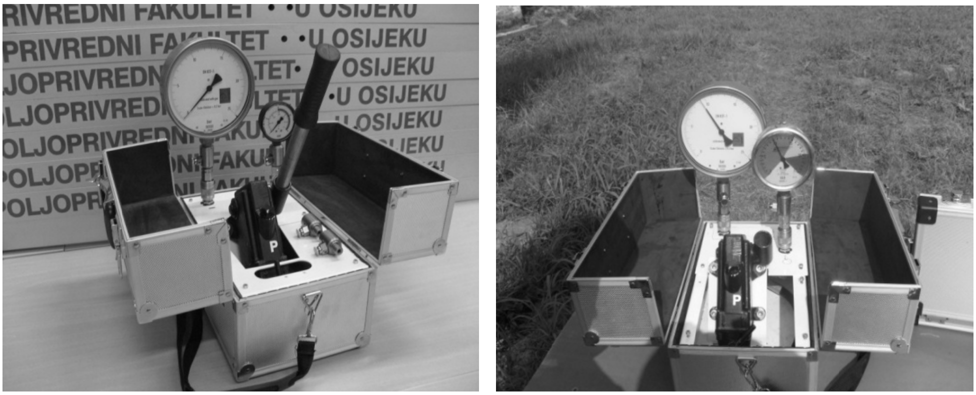
Prema normi *EN 13790* dozvoljeni pad kapaciteta crpke može najviše iznositi do 10 % od nazivnog kapaciteta. Kod svih ispitivanih prskalica i raspršivača, 83,55% ugrađenih crpki polučile su vrijednosti smanjenja kapaciteta unutar dozvoljenih 10%. Kontrola kapaciteta crpki mjerena je sa elektromagnetskim mjeračem prikazanim na slici 1. Skupni prikaz testiranih crpki prikazan je u tablici 2.



Slika 1 Elektromagnetni mjerač kapaciteta crpke tvrtke *Krohne*

Kontrola ispravnosti manometra

Komparator tlaka *Volos* (Slika 2.) prema standardu EN 837-1 posjeduje kontrolni manometar (valjani certifikat) sa klasom točnosti 0.6 te s mjernim područjem do 25 bar. Na uređaj *Volos* postavlja se kontrolni manomatar i manometar koji se treba provjeriti. Rezultati ispitivanih manometara prikazani su u tablici 2. Po normama u EU manometri koji se ugrađuju na tehničke sustave u zaštiti bilja moraju imati minimalni promjer od 63 mm te točnost manometra koji se ispituje mora biti ± 0,2 bar kada se radi o ispitnom području od 0 do 2 bar. Ako se radi o većem ispitnom području odstupanje može iznositi do ± 10 %.



Slika 2 Komparator tlaka Volos

Kontrola ispravnosti mlaznica

Mlaznice predstavljaju najveći problem pravilnog rada tehničkog sustava u zaštiti bilja. Vrlo je često da se izlazni otvor mlaznice brzo potroši pa se poveća protok s obzirom na tablično označenu vrijednost. Vrlo često imamo pojavu da se mlaznice začepe uslijed lošeg pročišćavanja tekućine. Europski standard nalaže da treba zamijeniti svaku mlaznicu koja ima protok manji ili veći od 10% s obzirom na tablične vrijednosti pri odgovarajućem radnom tlaku. Mjerenje protoka mlaznica na raspršivačima obavljeno je s uređajem domaće izrade koji na sebi ima menzuru za svaku ispitivanu mlaznicu, slika 3. Za mjerenje protoka tekućine na ratarskim prskalicama korišten je uređaj *AAMS*, slika 3. Skupni prikaz testiranih mlaznica prikazan je u tablici 2.

Pregled ratarske prskalice

Pregledavaju se svi važniji sustavi te je jako važno da se obavi ispitivanje površinske raspodijele tekućine, što nalaže norma *EN 13790*. Testiranje horizontalne raspodjele tekućine pri radu ratarske prskalice obavljeno je s uređajem s*pray scanner,* prikazanim na slici 4. Skupni prikaz testiranih prskalica sa prosječnim koeficijentom varijacije raspodjele tekućine prikazan je u tablici 2.

Slika 4 Ispitivanje površinske raspodijele tekućine kod nošene ratarske prskalice

REZULTATI ISTRAŽIVANJA

Istraživanje je obavljeno u pet slavonsko - baranjskih mjesta: Slavonski Kobaš i Grabarje (Brodsko – posavska županija), Pleternica (Požeško – slavonska županija), Trpinja (Vukovarsko – srijemska županija) i Branjin Vrh (Osječko – baranjska županija). Samo na ovih pet lokaliteta pregledano je 92 tehnička sustava u zaštiti bilja. Većinom su to nošeni strojevi malih radnih zahvata, sa malim obujmom spremnika. Skupni prikaz tehničkih karakteristika ispitanih strojeva prikazan je u tablici 1.

Tablica 1 Tehničke karakteristike ispitanih strojeva

	Prosječni radni zahvat (m)	Prosječni obujam spremnika (l)	Vučeni strojevi (%)	Nošeni strojevi (%)	Pregledano strojeva (kom.)
Slavonski Kobaš	10,00	404,21	0	100	21
Pleternica	10,00	412,63	26,31	73,69	19
Trpinja	11,90	587,33	5,88	94,12	23
Grabarje	10,25	541,66	0	100	12
Branjin Vrh	10,88	407,25	17,64	82,36	17
Prosjek ($\overline{X}$)/ Ukupno (Σ)	10,60	470,61	9,96	90,03	92

Testiranje je provedeno prema EN 13790 (I,II) koji je glavni temelj europske direktive *2009/128/EC i 2006/42/EC.* Na strojevima je pregledavana:

- ispravnost crpki,
- ispravnost mlaznica,

- ispravnost manometara,
- pojava kapanja/curenja tekućine na vodovima nakon i za vrijeme rada,
- ispravnost krila prskalica,
- horizontalna raspodjela tekućine pri radu prskalice,
- broj okretaja PVT – a,
- kapacitet miješanje tekućine,
- integralnost tri spremnika tekućine i dr.

Nabrojeni su samo važniji elementi europske norme, a zbirni rezultati testiranih tehničkih sustava u zaštiti bilja prikazani su u tablici 2.

Tablica 2 Neki od testiranih parametara važnih za rad tehničkih sustava u zaštiti bilja

	Ispravno crpki (%)	Ispravno mlaznica (%)	Ispravno manometara (%)	Kapanje/curenje na vodovima (%)	Ispravno krila (%)	KV (%) ($\overline{X}$)
Slavonski Kobaš	89,00	36,25	41,66	29,33	63,97	23,47
Pleternica	85,15	39,69	40,28	32,22	67,34	20,14
Trpinja	85,30	29,41	44,11	52,94	64,51	23,12
Grabarje	83,34	41,66	56,39	40,67	66,66	21,17
Branjin Vrh	74,97	33,28	48,39	49,85	51,27	24,89
Prosjek ($\overline{X}$)	83,55	36,05	46,16	41,00	62,75	22,55

ZAKLJUČCI

Na temelju gore navedenih istraživanja mogu se donijeti slijedeći zaključci:

- ispitani strojevi raspolažu sa malim eksploatacijskim potencijalom (mali radni zahvati – prosječno 10,60 m, mali obujmi spremnika – prosječno 470,61 l) te su to većinom nošeni strojevi – 90,03%
- od ukupno 92 ispitana stroja na njih 83,55 % crpka ostvaruje potrebni kapacitet
- samo 36,05% ispitanih mlaznica je u ispravnom stanju
- od ukupno 92 ispitana stroja samo na njih 46,16% je utvrđen pravilan rad manometra
- kapanje/curenje tekućine na vodovima utvrđeno je na 41,00% ispitanih strojeva
- na 62,75 % ispitivanih strojeva utvrđena je ispravnost krila prskalice

Prema navedenim zaključcima može se vidjeti da stanje tehničkih sustava u zaštiti bilja u Slavoniji i Baranji je jako loše i od ukupno broja ispitanih strojeva njih samo 17 može zadovoljiti EN 13970. Trenutno utvrđeno stanje je zabrinjavajuće, a do ulaske Hrvatske u EU navedeni problemi morati će se ispraviti, jer na snagu stupa novi zakon o obaveznom i redovnom testiranju tehničkih sustava u zaštiti bilja prema EN 13790 standardu.

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TESTING TEHNICAL SYSTEMS IN PLANT PROTECTION IN REPUBLIC OF CROATIA

Đ. BANAJ, V. TADIĆ, D. PETROVIĆ

Towards to adjustment of croatian family ranch on new laws in EU, testing tehnical systems in plant protection and lectures were conducted financed with money of Dutch charter. The works were carried out with employees of Machinery Department from Agricultular Faculty in Osijek. In this program, 17 agricultular organization participated from area of Slavonija i Baranja. The goal of this lectures was to teach machine handlers and to test their machinery. On force in EU is the 2009/128/EC i 2006/42/EC directive. This directive have EN 13790 (I,II) standard for testing tehnical systems in plant protection. With entering Croatia in EU, this directives become actual and we must to pay attencion with this.

Key words: *tehnical systems in plant protection, handler, testing, EN 13790 standard*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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PRIMERJAVA UČINKOVITOSTI ENOREDNEGA IN SAMOHODNEGA SILAŽNEGA KOMBAJNA NA MANJŠIH KMETIJAH

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POVZETEK

Siliranje, kot način konzerviranja krme, je eden pomembnejših postopkov spravila krme. Na manjših kmetijah se vedno pogosteje pojavlja vprašanje, kakšen stroj se naj uporablja, da je delo čimbolj učinkovito, silaža pa kakovostna. V ta namen smo primerjali učinkovitost siliranja koruze z enorednim silažnim kombajnom SIP Vihar 40 in samohodnim silažnim kombajnom Class Jaguar mega na manjših kmetijah. Z enorednim kombajnom smo za napolnitev ene prikolice (9,1 m^3) porabili 12,92 min oziroma 4-krat več časa kot z samohodnim kombajnom (2,86 min). Za žetev 1 ha koruze smo porabili z enovrstnim kombajnom 5,9 h, s samohodnim pa 2,2 h. Površinska storilnost je bila pri samohodnem kombajnu za 77% večja kot pri enorednem. Siliranje z samohodnim kombajnom je organizacijsko težje, saj za učinkovito izvedbo del potrebujemo vsaj 2-3 krat več ljudi in strojev kot pri siliranju z enorednim kombajnom. Z tega vidika je za siliranje na manjših kmetijah veliko primernejši enoredni kombajn kot večredni.

Ključne besede: *Silokombajn, koruza, silaža, spravilo*

UVOD

Koruzna silaža je v Sloveniji najbolj razširjena zimska krma na govedorejsko usmerjenih kmetijah in je tudi najcenejši vir energije za prehrano govedo. V Sloveniji je približo 480.000 goved in pri večini koruzna silaža predstavlja vsaj del obroka. V manjši meri se koruzna silaža uporablja za krmljenje drobnice in drugih živali.

Koruza za silažo se v Sloveniji prideluje na 26.802 ha. Pridelki koruzne silaže so od leta do leta različni in so odvisni od vremenskih razmer. V letu 2007 je bil pridelek koruzne silaže 42.1 tone / ha, največji pridelek je bil leta 2005 v katerem se je pridelalo kar 47.5 t/ha koruzne silaže. Najmanjši pridelek v zadnjem desetletju je bil leta 2003, pridelalo se je samo 29.379 t/ha koruzne silaže (Statistični letopis Republike Slovenije, 2007).

Siliranje je eden pomembnejših postopkov v pridelovanju krme. Kot način konzerviranja ga poznamo več tisoč let, intenzivno pa se je začela ta tehnika razvijati šele v 19. stoletju (Andrae et al., 2001). Čeprav je mehanizacija ključnega pomena pri siliranju, so za kakovost silaže pomembni tudi drugi dejavniki (npr. lastnosti krme, primernost silosa, strokovnost pri pripravi silosa). Od začetkov siliranja do danes se je kmetijska mehanizacija občutno izboljšala. Vedno večja ponudba silažnih kombajnov in vse višja tehnična raven sta rezultat prizadevanj in zahtev po večjih delovnih učinkih, zanesljivosti pri delu, natančnosti rezi in zdrobljenosti zrnja. Tako je danes na trgu veliko število različnih tipov kombajnov, ki se razlikujejo po delovanju, velikosti in učinkovitosti. Veliko število in raznolikost strojev pomenita danes še večji izziv pri nabavi primernega silažnega kombajna za manjšo (povprečno) slovensko kmetijo (Stekar, 1999).

Zaradi pomanjkanja raziskav, povezanih s siliranjem koruze na manjši kmetijah, se vedno pogosteje pojavlja vprašanje, kakšen stroj naj se uporablja. Cilj raziskave je bil analizirati podatke, dobljene iz meritev dveh različnih strojev (postopkov) za siliranje koruze ter iz njih ugotoviti izkoriščenost in primernost stroja za siliranje koruze na manjših kmetijah.

METODE

Poskus se je izvajal na dveh njiva. Njiva 1 je v velikosti 1,615 ha in je v obliki pravokotnika z majhnim odstopanjem vzporednih nasprotnih stranic, dolga približno 190m in v širino 85m. Njiva 2 je bila nepravilne oblike in v velikosti 7.7 ha, kar je vzelo nekaj več časa pri siliranju. Na dan siliranja koruzne silaže je bilo sončno in zmerno vlažno vreme. Zemlja se je dopoldan rahlo oprijemala pnevmatik kasneje pa se je zemlja posušila.

Opis strojev

V poskusu smo uporabljali enoredni kombajn SIP Vihar 40 in samohodni kombajn Class Jaguar 695 Mega (slika 1).

Slika 1 Enoredni kombajn SIP Vihar 40 (levo) in samohodni kombajn Class Jaguar 695 Mega (desno)

Silo kombajn Vihar 40 je enoredni nošeni silažni kombajn, namenjen siliranju cele rastline. Vihar 40 je lahek, vendar zmogljiv enoredni bobnasti silokombajn. Odlikuje ga mala potrebna pogonska moč. Ima par vlečnih valjev z noži, ki zagotavljajo čist odrez koruznega stebla in par prilagodljivih dozirno - stiskalnih valjev, ki dozirata koruzo v rezalnik. Rezalni sklop z bobnom s 16 noži in drobilna plošča so garant za kratek in eksakten rez ter zdrobljenost zrna. Dolžino reza je možno regulirati od 4 do 6 mm. Pogon do rezalnega sklopa je kardanski, ostali sklopi pa so gnani z verižnimi pogoni. Upravljanje izmetalne cevi je hidravlično, usmerjevalne lopute pa z pleteno žično vrvjo. Opremljen je z napravo za brušenje nožev. Enoredni kombajn je bil gnan z traktorjem Deutz 6206c.

Samohodni kombajn Class Jaguar 695 Mega je štiri vrstni kombajn s šest valjnim dizelskim motorjem z močjo 185kW. Ta tip kombajna ima mehanski pogon z menjalnikom s tremi prestavami za vožnjo naprej ter eno za vzvratno vožnjo. Hitrost vožnje se uravnava stopenjsko. Rezalni sklop tega kombajna je bobnaste izvedbe. Classovi silokombajni delujejo s tremi dovajalnimi valji, valjem za vnos in dvema valjema za stiskanje. Rastlinski material sprejemajo neprekinjeno in ga s pomočjo močnih nastavljivih vlečenih vzmeti stisnejo in ga kompaktnega dovajajo v rezalni boben. Za boljši sprejem pridelka ima sprednji zgornji valj še posebno velik premer. V nasprotju s spodnjimi valji iz umetnih snovi je zgornji valj iz nemagnetičnega jekla. Razlog za to, da so Class-ovi kombajni serijsko opremljeni z detektorjem kovin, ki stroj varuje pred kovinskimi deli. Zamenljiva obrabna pločevina na levi in desni strani na območju zelo stisne krmo ter ščiti ohišje pred obrabo med obratovanjem. Reverzijsko stikalno gonilo ponuja vozniku precejšno udobje. Kombajn je bobnaste izvedbe. Boben poganja klinasti jermen. Pri hidravličnem vklopu je napetost jermena konstantna. Dva vijaka varujeta pogon bobna pred nenadno obremenitvijo. Odpade tudi naporno brušenje nožev, saj je pri Class-ovih kombajnih postopek brušenja popolnoma avtomatski.

Zmogljivosti strojev so v veliki meri odvisne tudi od strojnika, zato sta udobnost vožnje in upravljanje prvovrstna. Samohodni kombajni so serijsko opremljeni z veliko prostorno kabino, ki ščiti voznika pred slabim vremenom ter hrupom. Filtrirna naprava po ohranja zrak v kabini čist. Kombajn je opremljen s centralnim informatorjem, ki omogoča stalno kontrolo nad najpomembnejšimi funkcijami stroja.

Meritve

Vse dogodke smo kronografsko spremljali na dveh kmetijah s podobnimi parcelami in dobljene podatke meritev statistično obdelali ter iz njih ugotovili primernost izkoriščenosti posameznega stroja za siliranje koruze na manjših kmetijah. Parceli smo izmerili s pomočjo merilnega traka, nato smo odmerili 1 ha površine na katerih smo kronografsko spremljali vse spremembe katere vplivajo časovno na storilnost stroja.

Merili smo naslednje parametre:

- Volumen prikolic ter čas žetve ene prikolice: silirno maso smo ocenili iz števila in volumna prikolic. Z volumnom smo lahko izračunali maso, ki je bila požeta in prepeljana v silos. Hkrati pa smo dobili volumensko storilnost stroja v eni uri.

$$\text{Volumenska storilnost} \left(\frac{\mathrm{m}^3}{\mathrm{ha}}\right) = \frac{\text{Volumen } (\mathrm{m}^3)}{\check{C}as\ (h)} \quad (1)$$

- Žetev: Merili smo čas od trenutka, ko smo se pripeljali na njivo in do trenutka, ko je bila požeta zadnja rastlina na njivi. Pri tem smo upoštevali vse dejavnike, ki vplivajo na čas žetve. Merili smo čas žetve, dejanski čas žetve, obračanje, priklapljanje prikolice in čas čakanja na prihod praznih prikolic.
- Dejanski čas žetve smo izračunali tako, da smo odmerjeni žetvi odšteli čas obračanja na koncu njive in čas, ko je kombajnist čakal na odvoz silaže.

Dejanski čas žetve (min) = Žetev (min) - [čas obračanja (min) + čas mirovanja (min)] (2)

- Hitrost žetve: Z merilnim trakom smo izmerili dolžino njive, nakar smo s pomočjo povprečnega izmerjenega časa žetve ene vrste izračunali hitrost žetve koruze s pomočjo enačbe:

$$\text{Hitrost žetve}\left(\frac{\text{m}}{\text{s}}\right) = \frac{\text{Pot (m)}}{\text{Čas (s)}} \quad (3)$$

- Čas obračanja na ozarah: Čas obračanja na ozarah je čas, ko je kombajn delal, vendar izven območja, kjer je bila posejana koruza. To pomeni čas prehoda iz ene vrste v drugo.

Obračanje na ozarah (min) = Število prehodov * Povprečni čas obračanja (min) (4)

- Priklop - odklop prikolice: Pri siliranju z enorednim kombajnom smo prikolice pred žetvijo vsakokrat priklopili na kombajn. S tem smo manjšali tlačenje zemlje in povečali izkoriščenost posameznih strojev. Hkrati pa smo prihranili stroške goriva, saj smo potrebovali samo en traktor za izmenični odvoz dveh prikolic na katere smo želi koruzno silažo. Merili smo čas odklopa polne prikolice in čas priklopa prazne prikolice h kombajnu.
    - Transport: Transport predstavlja danes skoraj 50 % stroškov v kmetijstvu. Pri transportu moramo v čim krajšem času prepeljati čim več tovora. Merili smo čas vožnje od njive do silosa in obratno. Dolžino poti pa smo izmerili s pomočjo GPS naprave. GPS napravo smo namestili v traktor in izmerili dolžino poti ter čas, porabljen za vožnjo od njive do silosa.

$$\text{Transport}\left(\frac{\text{t}}{\text{h}}\right) = \frac{\text{Pot (km)}}{\text{Hitrost}\left(\frac{\text{km}}{\text{h}}\right)} \quad (5)$$

    - Praznjenje prikolice: Pri tem smo merili čas od prihoda traktorja s prikolico na silos, praznjenja in odhoda s silosa. Hitrost odlaganja tovora je odvisna predvsem od načina izvedbe sistema za praznjenje prikolice (kiper, transportni trak, pomična stena).
    - Tlačenje: Intenzivnost tlačenja je mogoče izraziti kot produkt med maso traktorja in urami tlačenja na tono silaže. Merili smo čas tlačenja in maso, ki se je pripeljala v silos. Maso posameznega stroja za tlačenje pa smo prepisali s stroja.

- Stroški: Stroške dela, ki so nastali pri siliranju koruze smo izračunali s pomočjo kataloga stroškov kmetijske in gozdarske mehanizacije (Dolenšek, 2008). Na vsaki kmetiji smo popisali delovno mehanizacijo vključeno v potek siliranja, ter s pomočjo kataloga izračunali stroške. To smo naredili za vsak posamezen stroj in na koncu vse stroške sešteli.

REZULTATI Z RAZPRAVO

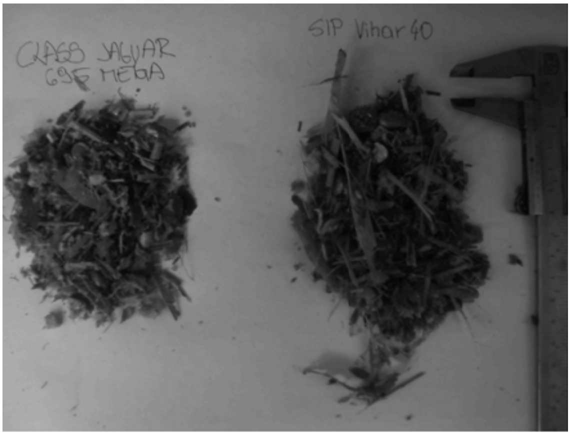
Samohodni kombajn Class Jaguar 695 Mega in SIP Vihar smo primerjali v delovni učinkovitosti ter izkoriščenosti pri delu na manjših kmetijah. Primerjali smo tudi stroške, ki so povezani z različnima tehnikama spravila koruzne silaže.

Hitrost žetve in učinkovitost rezi

Hitrost žetve je bila bistveno večja pri Classovem samohodnemu kombajnu (4,3 km/h) kot pri enorednem Sipoven kombajnu (3,5 km/h). Enoredni kombajn pri višji hitrosti ni dosegal zadovoljive razrezanosti koruzne silaže. Dolžina in kakovost rezi sta pomembna kazalca učinkovitosti kombajna (slika 2).

Pri Classovem kombajnu je razrezanost rastlinskega materiala enakomernejša, natančnejša in drobnejša kot pri enorednem kombajnu. Povprečni delež delcev pri samohodnem kombajnu, ki so bili večji od 1 cm, je bil 8 %.

Pri Sipovem kombajnu je bila rez neenakomerna v primerjavi s samohodnim Classovim kombajnom. Delež delcev, večjih od 1 cm, je pri Sipovem kombajnu v povprečju 13 %.



Slika 2 Dolžina rezi Class Jaguar 695 Mega (levo) in SIP Vihar 40 (desno) (Hrastel, 2008)

Čas obračanja na ozarah štirirednega samohodnega Class Jaguar 695 Mega kombajna na 1 ha (8,8 min) je za 80 % krajši kot čas obračanja enorednega SIP Vihar 40 kombajna (46,4 min). Samohodni kombajn žeje štiri vrste hkrati in posledično ima štirikrat manj obračanja kot enoredni kombajn. Število obratov je vedno povezano tudi z dolžino njive (Preglednica 1).

Preglednica 1 Primerjava časa žetve ene vrste na dolžini njive

	SIP Vihar 40	Class Jaguar 695 Mega
Dolžina njive	190 m	308 m
Povprečni čas žetve 1 vrste	3,23 min	4,27 min

Pri enorednem kombajnu smo pred vsakim ciklusom žetve h kombajnu priklopih prikolico. Tako smo v povprečju porabili nekaj dodatnega časa (2 min), kar je podaljšalo skupni čas siliranja. Skupni čas preklapljanja je znašal na površini 1 ha 40 min od skupnega časa žetve 359,82 min ali 11 %. Na ta način smo preprečili tlačenje zemlje z drugim traktorjem za dobrih 310 min. Pri Classovem samohodnem kombajnu te operacije ni bilo (preglednica 2).

Preglednica 2 Primerjave časa žetve

	SIP Vihar 40	Class Jaguar 695 Mega
Žetev	258,52 min	65,7 min
Čakanje prikolic	15 min	58,85 min
Obračanje	46,4 min	8,8 min
Priklop-odklop prikolic	40 min	/
SKUPAJ	359,82 min	133,35 min

Dolžina poti odvoza koruzne silaže pri enorednem kombajnu od njive do silosa je bila v eno smer 500 m. To pot smo v obe smeri ponovili 20-krat, zato je skupna razdalja transporta pri spravilu enega hektarja koruze znašala 20 km in smo jo opravili v 80 min. Tako znaša povprečna hitrost vožnje 20 km/80 min.

Transportna pot pri spravilu s Classovim kombajnom je v obe smeri merila 4 km, pri spravilu enega hektarja koruze smo jo ponovili 10-krat. Skupna razdalja je merila 40 km in je bila odpravljena v 160 min. Tako znaša povprečna hitrost vožnje 40 km/160 min. Pri obeh načinih spravila se je pokazalo, da je povprečna hitrost transporta znašala približno 15 km/h. Teoretična razlika med skupnim časom transporta bi morala biti 4-krat večja pri večji transportni razdalji 2 km kot pri krajši razdalji 500 m. Vendar je bila razlika samo 1-krat večja zaradi večjega volumna prikolic.

Povprečni volumen prikolic pri žetvi s SIP-ovim kombajnom je namreč znašal 9,1 m^3, povprečni volumen pri žetvi s Classovim kombajnom pa 20,2 m^3. Na isti razdalji smo v istem času prepeljali 55 % več koruzne silaže pri žetvi s Classovim kombajnom, saj smo uporabili prikolice večjega volumna.

Preglednica 3 prikazuje povprečne čase delovnih operacij za Sip Vihar 40 in Class Jaguar 695 Mega.

Razlika v skupnem času praznjenja prikolic je bila različna na obeh kmetijah. Na kmetiji, kjer so želi z enorednim kombajnom, je skupni čas praznjenja prikolic velik in znaša 151,1 min. Na ta čas je vplivala tehnika praznjenja prikolic, saj so morali za vsako praznjenje sneti eno stranico in jo po praznjenju spet pritrditi nazaj na prikolico. To dodatno delo pa je povečalo skupni čas praznjenja. Čas, ki je bil potreben za praznjenje ene prikolice, je znašal 7,55 min.

Preglednica 3 Povprečni časi delovnih operacij

	SIP Vihar 40	Class Jaguar 695 Mega
Povprečni čas obračanja na ozarah (s)	35	44
Povprečni čas priklopa odklopa prikolice (min)	2	/
Čas vožnje z njive in silosa ter obratno (min)	4	16
Praznjenje prikolic (min)	151,1	14,6
Tlačenje (min)	208,2	118,9

Drugače pa je bilo na kmetiji, kjer so želi s samohodnim kombajnom. Skupni čas praznjenja prikolic je tam znašal samo 14,96 min. Torej je bil čas praznjenja ene prikolice le 1,49 min. Na tako kratek čas pa je bistveno vplivala sodobna tehnika prikolic.

Intenzivnost tlačenja na obravnavanih kmetijah naj ne bi bila po navedbah Johnsona in Harrisona manjša od 283 h kg/tono. Na kmetiji, kjer so tlačili samo z enim traktorjem Deutz Fahr Agrofarm 100 z maso 3700 kg, te vrednosti niso dosegli, kljub daljšim časom tlačenja (208,72 min). Dosežena vrednost je znašala 257,43 h kg/tono koruzne silaže. Drugače pa je bilo na kmetiji, kjer so istočasno tlačili trije stroji: Reform Mounty - 2120 kg, Zetor 4711 - 2150 kg in ICB kombinirka - 6230 kg, saj so dosegli 359,83 h kg/tono koruzne silaže.

Razlika v površinski storilnosti je bila kar za 77 % večja pri samohodnem kombajnu kot pri Sipovem. Do razlike je prišlo zaradi večje hitrost žetve (4,3 km/h) samohodnega kombajna in žetve štirih vrst hkrati. Medtem ko smo s Sipovem želi pri 3,5 km/h le eno vrsto.

Ovrednotenje stroškov

Stroški so izračunani s pomočjo kataloga stroškov (Dolensek, 2008). Stroške smo izpisali iz kataloga in jih podali v dveh preglednicah (4 in 5).

Preglednica 4 Stroški žetve s samohodnim Classovim kombajnom

Stroj	Čas (h)	Stroški (h)	Strošek/ha (€)
Class Jaguar 695 Mega	1,09	120,57	132,0
New Holland Ts 135+ Tehnostroj 8t	2,22	41,52	92,17
New Holland TD 100+ Tehnostroj 8t	2,22	28,27	63,75
Class Ares 120+ Fliegel Gigant ASW 160	1,80	40,41	72,09
Fend Farmer 412 Vario+ Fliegel Gigant ASW 160	1,80	40,41	72,09
Zetor 4711	1,97	9,00	17,73
Reform Mounty	1,97	35,00	68,95
ICB kombinirka	1,97	27,00	53,19
Skupaj			571,97

V preglednici 4 in 5 so kot osnova za izračun cene storitve prikazani stroški posamezne delovne operacije. Upoštevati je bilo potrebno, da cena storitve poleg stroškov zajema tudi ceno delavca oziroma zaslužek ponudnika storitve, ki pa od ponudnika do ponudnika variira. Cena žetve pri nas stane za 1 ha koruze s samohodnim kombajnom od 140-180 evrov/ha.

V našem primeru je žetev s samohodnim kombajnom za 1 ha koruzne silaže znašala 571,97 evra/ha, za enorednega pa 301,4 evra/ha v primeru celotne najete usluge. Glede nato, da smo vsa dela pri siliranju z enorednim kombajnom izvedli z domačimi stroji, kar je dodatno znižalo stroške, saj se lastno delo na kmetiji ne računa, nam je bil glavni strošek le gorivo.

Preglednica 5 Stroški žetve z enorednim SIP-ovim kombajnom

Stroj	Čas (h)	Stroški (h)	Strošek/ha (€)
Deutz torpedo 6206c + SIP Vihar 40	5,99	22,89	137,27
Zetor 4711	5,99	9,00	53,97
Dve tehnostroj prikolici	5,99	2*2,81	33,76
Deutz Fahr Agrofarm 100	3.4	22,04	76,4
Skupaj			301,4

V raziskavi smo primerjali dva načina žetve, transporta in tlačenja koruze za silažo. Uporabljeni samohodni kombajn Class Jaguar 695 Mega je imel nazivno moč motorja 3-krat večjo v primerjavi s pogonskim traktorjem enorednega Sip-ovega kombajna. Rezultati testiranja kažejo, da porabimo za napolnitev ene Tehnostrojeve prikolice z volumnom 9,1 m^3 s samohodnim kombajnom 4-krat manj časa (2,86 min) v primerjavi z enorednim kombajnom (12,92 min). To razliko smo pričakovali, saj je uporabljen samohodni kombajn porabil 3-krat manj časa za obračanje kot enoredni. Število obračanj je namreč vedno povezano z dolžino njive, posledično pa je od dolžine njive odvisen tudi čas za napolnitev prikolice s silažno maso.

Za žetev 1 ha koruze smo z enorednim kombajnom SIP Vihar 40 porabili 63 % več časa, kot pri žetvi s samohodnim kombajnom Class Jaguar 695 Mega. Delovna storilnost enorednega kombajna je bila 5,9 h/ha, delovna storilnost samohodnega kombajna pa 2,22 h/ha. Pri samohodnem kombajnu je bila izkoriščenost stroja relativno slaba 49,26 % in jo prepisujemo prepočasnemu odvozu koruzne mase z njive. Časi čakanja na prihod praznih prikolic so bili v povprečju 5,88 min.

Izkoriščenost enorednega kombajna je bila večja in je znašala 71,8 %, vendar bi bila lahko še večja, a smo porabili veliko časa za priklop in odklop prikolic (40 min), ter 3-krat več časa za prehod iz vrste v vrsto.

Poleg obračanja je pomembno omeniti, da samohodni kombajn bolj enakomerno zreže silažno maso in je zato boljša tudi končna kakovost silaže. Samohodni kombajn Class Jaguar 695 Mega rastlinski material zreže bolj natančno, enakomerno in drobno, zaradi tega je takšno silažo lažje potlačiti. Silažni material je bolj stisnjen, kar onemogoča aerobne procese, posledično pa omogoča hitrejši nastanek mlečne kisline. Silažo iz bolj zrezane koruze živali rajši jedo.

Enoredni kombajn je v večini last kmetov, ki sami silirajo koruzo in je zato glavni strošek gorivo. V primeru najema celotne usluge žetve z enorednim kombajnom, odvoza in tlačenja silažne koruze bi stroški znašali 301,4 evra/ha. Pri najemu samohodnega kombajna in ostalih strojev pa bi ti stroški znašali 571,97 evra/ha siliranja koruzne silaže. Siliranje z enorednim kombajnom je tako za manjše parcele in kmetije ugodnejše kot najem samohodnega kombajna.

Glede na rezultate poskusa menimo, da je za manjše slovenske kmetije siliranje s samohodnim kombajnom manj primerno. Čeprav s samohodnim kombajnom dosegamo bistveno večjo delovno storilnost kot z enorednim kombajnom, so stroški za 47,3 % večji. Upoštevati moramo, da žetev s samohodnim kombajnom zahteva večje število ljudi in strojev, ki pa jih v današnjem času na manjših kmetijah primanjkuje.

SKLEPI

V raziskavi smo prišli do naslednjih ugotovitev:

Samohodni kombajn Class Jaguar 695 Mega ima večjo površinsko storilnost (0,91 h/ha) kot enoredni kombajn SIP Vihar 40 (0,23 h/ha).

Siliranje s samohodnim kombajnom zaradi večje površinske storilnosti zahteva večje število strojev in delavcev, da lahko delo poteka tekoče in da so vsi ukrepi siliranja učinkovito in v zadostni meri izvedeni. V povprečju potrebujemo za siliranje s samohodnim kombajnom 2-3 krat več traktorjev, prikolic, strojev za tlačenje in delavcev kot pri siliranju z enorednim kombajnom. Površinska storilnost je zelo pomembna tudi pri odločitvi o nakupu ali najemu silokombajna. Glede na to storilnost se planira tudi celoten potek siliranja (odvoz koruzne silaže, masa stroja za tlačenje ...).

Prednost samohodnega kombajna je natančnejša in drobna rez rastlinskega materiala in boljša kakovost silaže.

Na manjših kmetijah je siliranje s samohodnim kombajnom predrago kljub pomembnim tehničnim prednostnim pred enorednim kombajnom.

Enoredni kombajn je ponavadi že v lasti kmeta, pri samohodnem pa kmetje najamejo storitev, zato je siliranje z lastnim enorednim kombajnom veliko cenejša kot najem storitve.

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COMPARISON OF EFFICIENCY OF SINGLE - ROW AND SELF - PROPELLED HARVESTER ON SMALL FARMS

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SUMMARY

Silage, as forage conservation method, is the most important processes of fodder harvesting. On smaller farms are increasingly the question, what kind of machine to use that the work is most effectively and silage quality. For this purpose, we compared the efficiency of maize harvesting by using single - row harvester SIP Vihar 40 and self - propelled Class Jaguar Mega on the smaller farms. Single - row harvester filled one trailer (9,1 m^3) in 12,92 min or it lasted 4 times longer than with the self - propelled (2,86 min). For harvesting 1 ha of maize 5,9 h was required with single - row harvester and 2,2 h with self - propelled harvester. Surface performance has been 77% higher in self - propelled harvester than in single - row harvester. The organization of harvesting maize for silage with self - propelled harvester is more difficult, since the effective performance of the work required at least 2-3 times more people and machines as the harvesting with single - row harvester. From this aspect the silage on the smaller farms are much more appropriate with single - row harvester than with self - propelled harvester.

Key words: *maize harvester, corn, silage, harvesting*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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THE MATHEMATICAL MODELLING OF THE VARIATION OF THE TECHNOLOGICAL FLOWS TO THE BULB OR TUBERCLE HARVESTERS

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SUMMARY

The original mathematical models of the variation of the materials flows during the technological process of the bulb or tubercle harvesters are presented in this paper. These technological flows are: the useful products flow, which contains the cleaned harvested products with corresponsive quality and which is generally evacuated in the rear of the working harvester like windrows, formed directly on smooth bands, especially prepared on the processed soil, or sometimes can be directed towards different storage accessories of the harvesters structure, or towards elevators for charging in carrier vehicles and the impurities flows, which are specific mainly to the different kinds of impurities separators from the harvesters structure and which are generally evacuated on the processed soil under the harvesters or on their lateral sides. The mathematical modeling of the variation of the materials flows during the technological process of the bulb or tubercle harvesters allows a precise estimation of the loading with materials of all the building blocks of the harvesters and constitutes an extremely useful instrument for the harvester designers.

Key words: *bulb or tubercle harvesters, mathematic modeling, technological flows*

INTRODUCTION

The mechanical harvesting of bulbs or tubercles is a complex process which implies the digging and the dislocation of the bulbs or tubercles from the soil bed wherein they are developed, the separation of the bulbs or tubercles from the impurities resulted after the digging and, according the situation, the evacuation of the cleaned product down of the soil like windrows or their charging in carrier vehicles. This working process is especially difficult because, after the digging, it results a very great amount of impurities (prevailingly fragments of soil with different dimensions but also vegetal remains, undeveloped bulbs or tubercles, boulders or stones) which frequently is many times greater than the quantity of useful products, and which must be removed. For this reason the separation of the impurities from the useful products becomes a difficult, but also an extremely important process for the quality of the useful products which requires both the application of different combinations of procedures for the extraction and the elimination of all kinds of impurities, and extended surfaces of the separating devices.

According to the demands of the harvesting technologies of the bulbs or tubercles and to the complexity of the harvesting machines there were developed two main categories of harvesting machines, namely: *bulb or tubercle diggers* and *bulb or tubercle harvesting combines*.

The bulb or tubercle diggers are harvesting machines with low complexity which dig, dislocate and make a preliminary cleaning of the useful products. Regularly, after the technological process, these kinds of machines evacuate the cleaned useful product directly on the soil, like windrows. Anyway, in certain cases, the bulb or tubercle diggers may be fitted with hoppers or storage platforms or with elevators for the charging of the processed useful products in carrier vehicles, these kind of harvesting machines being named bulb or tubercle *diggers and chargers*.

The structure of a bulb or tubercle digger is generally composed of *a digging device* (which is compact in the case of the bulb harvesters, and process one layer with many plant rows at one harvesting pass, and complex in the case of the tubercle harvesters, composed of one or many separate and independent digging devices, every independent digging device processing a certain plant row at one harvesting pass), an *impurities cleaning system*, regularly composed of successive separators of the same type or of different types and a *windrow formative device*. This kind of harvesters must be fitted with special *devices for the soil bands preparation* on which windrows of evacuated cleaned products are placed. The bulb or tubercle diggers and chargers have almost a similar structure, but in this case the devices for the windrow formation and for the preparation of the soil bands are replaced with *storage devices* or *elevators* for the cleaned products storing or charging. In most of the cases the bulb or tubercle diggers or bulb or tubercle diggers and chargers are harvesting machines working in aggregates with tractors, but rarely can they be self-propelled.

The bulb or tubercle harvesting combines are high capacity harvesting machines which process at a single pass many plant rows, which dig and dislocate the bulb or tubercle from the soil, perform an advanced separation of the impurities from the useful products (practically to a storage quality) and charge the cleaned useful products in carrier vehicles. The structure of the harvesting combines is composed of a digging device, generally similar with that from the diggers, of a very complex impurities cleaning system, and, as appropriate, of a storage hopper fitted with a evacuation device (when charging in the carrier vehicles is performed discretely during harvesting) or with a evacuation elevator (when charging in the carrier vehicles is performed concomitantly during harvesting). Generally the bulb or tubercle harvesting are self-propelled (in certain cases they work in aggregate with tractors) and it can be mentioned that the tubercle harvesting combines are much prevalent to the bulb harvesting combines.

In all the cases of bulb or tubercle harvesting machines the greatest zone of the technological flow takes place in the impurities cleaning system, which generally occupies the major part of the machines structure and has a determinative influence upon the form and the dimensions of these machines.

The impurities cleaning system of the bulb or tubercle harvesting machines is composed of a succession of separators, which can be of different types such as: *rolling, oscillating or vibratory screens* or *systems of rotary bitters or roles (inclined or eccentric)* which eliminates the impurities by means of a screening process (similar with the sifting process from the cereal cleaning), and which are specially used for the removing of soil fragments with lower dimensions than the useful products and also for other kinds of impurities that may be eliminated by this process, *brushing systems* or *elastic fingers separators* which are used for the elimination of the small and compact impurities like little stones or particles of soil adherent to the useful products, *pairs of extracting roll-mills*, *systems of retaining elastic rods* or *systems of extracting rolling screens* which extract and evacuate by grabbing impurities with a branched structure such as the vegetal remains, *the separators with inclined active surface (smooth or with fingers),* which separate and eliminate the impurities with irregular shapes or with edges, such as boulders, by their different character of friction with the active surfaces of the separators comparing with the behavior of the useful products, *pairs of pneumatic roll-mills* which eliminate by crushing the boulders with similar dimensions with the useful products, *classifying tables and platforms* for human operators, wherein takes place a final elimination of the remaining impurities from the useful product mass before its discharge to the storage hopper or to the charging elevator.

THE ANALISYS OF THE WORKING PROCESS OF THE BULB OR TUBERCLE HARVESTING MACHINES

The working process of the bulb or tubercle harvesting machines presumes the several main phases, indifferently of the complexity of the harvesting machines:

- the cutting and the taking up of soil portions wherein are developed the useful products of the bulb or tubercle cultures;
- the mobilization of the useful products from the taken up soil, and crumbling as intensely as possible of the remaining soil;
- the separation of the impurities from the useful products and the elimination of the extracted impurities;
- the evacuation of the cleaned useful products by discharging them to storage or transportation means or on the soil, like windrows.

For the purpose of achieving the phases of the working process of the harvesting machines, the material taken up by the machines from the cultures is transmitted successively to specialized organs assemblies. It can be mentioned that the transmission of the taken up material between successive specialized organs is done directly or by the medium of some conveyors which do not change the carried material from a quantitative or qualitative point of view.

So, the working process of the harvesting machines may be represented in systemic mode like in the structural scheme from figure 1.

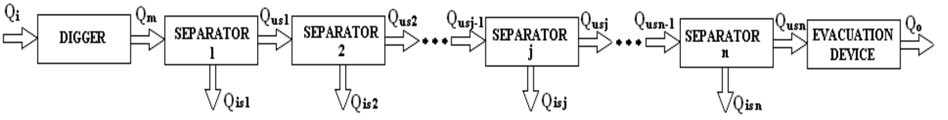

Fig. 1 The structural scheme of the working process of the harvesting machines

As it can be observed from the scheme from figure 1, the structural blocks of a bulb or tubercle harvesting machine, significant from point of view of the quantitative and/or qualitative modifications of the technological flows, are placed in a *serial* type structure. So, to an analyzed harvesting machine, each block of systemic structure complies with a real ensemble which achieves a precise function. From this point of view the significant blocks from the bulb or tubercle harvesting machines can be classified in three categories, namely:

- ***digger*** – is the block which corresponds to the device where there are realized the cutting and the taking up of the portions of soil wherein they are developed the useful products, the mobilization of the useful products from the taken up soil and the most intensely possible crumbling of the remaining soil;
- ***separators*** - are the blocks which correspond to the devices where there are extracted and eliminated different categories of impurities based on different principles of separation; from the point of view of the principle of separation the separator devices may be classified in separators which realize the working process by screening the impurities, generically named *screens* and separators which realize the working process by grabbing the impurities, generically named *extractors*; it can be mentioned that all the successive separators forms the impurities cleaning systems of the harvesting machines;
- ***evacuation device*** – is the block which corresponds to the device where the cleaned useful products are evacuated by discharging them to storage or transportation means or on the soil like windrows.

THE MATHEMATICAL MODELING OF THE TECHNOLOGICAL FLOWS VARIATION TO THE BULB OR TUBERCLE HARVESTING MACHINES

For the mathematical modeling of the technological flows variation to the bulb or tubercle harvesting machines, firstly there are established the individual mathematical models for each significant structural block of the machine, and thereafter it is established the mathematical model of the entire machine, seeing that the structural blocks of a bulb or tubercle harvesting machine are placed in a serial type structure.

The mathematical models of the technological flows variation for the categories and types of the significant structural block of the bulb or tubercle harvesting machine will be presented hereinafter:

The digger is the structural block wherein, during the technological process, by reason of the displacement of the harvesting aggregate with the working speed v_m [m/s], enters the flow Q_i [kg/s] constituted of portions of the soil bed wherein the useful products are developed, detached and taken up by the harvesting machine, and exit the flow Q_m [kg/s] constituted of a mixture of useful products and impurities which is transmitted to the impurities cleaning system of the harvesting machine.

Taking into account that to the great majority of bulb or tubercle harvesting machines, the organs of the digging device effectuate the dislocation of the useful products from the processed soil and the crumbling of the remaining fragment of soil, without their elimination, it results that quantitatively:

$$Q_m = Q_i \tag{1}$$

Qualitatively, the flow Q_m constituted of a mixture of materials, resulted from the digging device working process, can be divided, by point of view of the constitutive particles dimension, in the flow Q_u [kg/s] of constitutive materials with dimensions smaller than a reference value and in flow Q_{sf} [kg/s] of constitutive materials with dimensions greater than a reference value, namely:

$$Q_m = Q_u + Q_{sf} \tag{2}$$

If it is considered that the reference value is the minimum admissible dimension of bulbs or tubercles (indicated in standards), it results that the flow Q_u, named hereinafter *useful flow*, is constituted of useful products and impurities with dimensions greater than the reference value, while the flow Q_{sf} is constituted only of impurities with dimensions lower than the reference value, and will be hereinafter named *separable fragments flow*.

It can be mentioned that, from the point of view of the impurities elimination inside of the impurities cleaning systems, is very favorable a very pronounced crumbling of the remaining fragments of soil in the digging device, but the intensity of the soil fragments crumbling is limited by the eventuality of damaging the useful products, which is not permitted in any part of the technological process.

The *screen* type separator is the structural block wherein, during the technological process, separates by screening the impurities with lower dimensions than the reference dimension of the screen from the mixture of materials submitted to the separation process. In the structure of the bulb or tubercle harvesting machines are considered as *screen* separators, all the separators which eliminate the impurities by a process of screening or similar. The most encountered categories of screen separators in the construction of the bulb or tubercle harvesting machines are: the rolling, oscillating or vibratory screens and the systems of rotary bitters or roles (inclined or eccentric).

If it is considered that the current separator j from the structural scheme (see figure 1) is a screen, which has as reference dimension (the dimension of the slots, of the meshes or of the spaces between bitters or roles), the minimum admissible dimension of bulbs or tubercles (for example: the minimum admissible dimension for consumption onion bulbs or potato tubercles), then, in the screen will enter the raw flow Q_{usj-1} [kg/s] and will exit the useful flow Q_{usj} [kg/s] and the separable fragment flow Q_{isj-1} [kg/s]. Taking into account that raw flow Q_{usj-1} come from the digging device, it has the form:

$$Q_{usj-1} = Q_{uj-1} + Q_{sfj-1} \tag{3}$$

namely it is composed of a useful fraction which have the dimensions lower than the reference value of the screen and an impurities fraction which have the dimensions greater than the reference value of the screen.

For the mathematical modeling of the working process of the screen separators it is used a consecrated model wherein are envisaged the following parameters (see figure 2): *the specific load of the screen* q [kg/m.s] which is defined as the ratio between the material flow able to be separed during the working process and the effective width of the screen, *the length of the screen* L [m], *the specific load to the entrace on the active surface of the screen* q_1 [kg/m.s], *the specific load to the distance x from the entrace on the active surface of the screen* q_x [kg/m.s], *the specific load to the exit of the active surface of the screen* q_{1L} [kg/m.s], *the elementary specific load of impurities which are separating and are evacuated at the distance x from the entrace on the active surface of the screen* dq_x [kg/m.s] and *the elementary length of the screen* dx [kg/m.s].

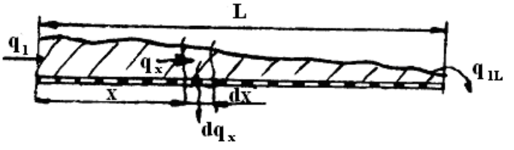

Fig. 2 The scheme of the impurities separation process on screen separators

If it is considered that the elementary specific flow of material which is separated on the elementary length unit, in a certain transverse section of the screen, is proportional with the specific load from this section and if is noted the proportionality coefficient with μ, which is defined as separation coeficient, indicator of the probability that the particles which can be separated pass through the slots of the screen, then it can be written:

$$-\frac{dq_x}{dx} = \mu \cdot q_x \tag{4}$$

The minus sign is because of the fact that the function q_x decreases with x.

The relation 4 is a differential equation which describes the material separation process on the surface of the screen. Beeing a equation with separable variables and considering that the coefficient μ is constant along all the lenght of the screen, that can be integrated, resulting:

$$q_x = C \cdot e^{-\mu \cdot x} \tag{5}$$

where C is an integration constant which is determinate by applying the conditions from the entrance of the screen ($x = 0$ and $q_x = q_l$), in this case the relation 5 becomes:

$$q_x = q_1\ e^{-\mu \cdot x} \tag{6}$$

If in the relation 6 are applied too the conditions from the exit of the screen ($x = L$ and $a_x = q_{1L}$), it results the expression of the specific load to the exit of the active surface of the screen flow, namely the specific flow of material which must be separated along the active surface of the screen but is not separated.

$$q_{1L} = q_l\ e^{-\mu \cdot L} \tag{7}$$

The parameter which defines the quality of the separation is named *the precision of separation ξ* and indicates the rate of the specific flow of material which must be separated along the active surface of the screen but is not separated, i.e. the ratio between q_{1L} and q_l. Considering the relation 7, it results the expression of the precision of separation ξ, namely:

$$\xi = e^{-\mu \cdot L} \tag{8}$$

So, the precision of separation ξ is the main parameter which characterizes a screen separator from the point of view of its efficiency.

If the conclusions of this mathematic model are applied in the concrete case of the current separator j, of screen type, then there can be determined the expressions of the exit flows Q_{usj} and Q_{isj}, in function with the entrance flow Q_{usj-1} (see relation 3), namely:

$$Q_{usj} = Q_{uj-1} + \xi_j \cdot Q_{sfj-1} \tag{9}$$

$$Q_{isj} = (1 - \xi_j) \cdot Q_{sfj-1} \tag{10}$$

Analyzing the relation 9 and 10, it results therefore that to a screen separator, the *exit flow* is composed of two fractions, namely: the *useful flow*, which has the same value as to the exit of anterior structural block (i.e. passes unmodified) and the *flow of separable fragments, but they are not separated*, whose value depends on the precision of separation ξ_j of the screen. Also, the flow of separated impurities depends of the precision of separation of the screen too.

The *extractor* type separator is the structural block which separates by different procedures (entrainment, retention, friction, grabbing, brushing, crushing etc.) from the mixture of materials submitted to the separation process, the impurities which may be separated by these procedures, like: vegetal remains, soil adherent to the useful products, stones, boulders (mainly those with prismatic shape or with edges). The categories of *extractor* separators most frequently met in the construction of the bulb or tubercle harvesting machine are: *brushing systems* or *elastic fingers separators*, *pairs of extracting roll-mills*, *systems of retaining elastic rods* or *systems of extracting rolling screens, separators with inclined active surface, smooth or with fingers*, *pairs of pneumatic roll-mills*, *classifying tables and platforms for human operators*.

If in the structural scheme from figure 1, it is considered that the current separator j is *extractor*, this will have the entrance and exit flows: Q_{usj-1}, Q_{usj}, Q_{isj-1}, Q_{uj-1}, and Q_{sfj-1}, with the same significations and expressions as in case of screen separator. The working process of the *extractor* separators differs from a type to another and assumes the extraction and the elimination of the impurities by specific procedures from the mixture submitted to the process. The quality of the working process of the extractors depends of a multitude of factors, namely: the used harvesting technology, the crop and soil characteristics, the moisture of the soil at harvest, the useful products characteristics, the ability of the operator to fit the separators in relation with the field conditions etc., and can be quantified by a subunitary index ζ, named *coefficient of extraction*, which represents the ratio between the extracted impurities mass and the mass of the mixture of material submitted to the separation process. Because of the multitude of factors that ζ depends on, it can take values in a very wide range, named coeficient of impurities extraction. In this case, the expressions of the exit flows Q_{usj} and Q_{isj} in function with the entrance flow Q_{usj-1} are:

$$Q_{usj} = Q_{usj-1}\cdot(1- \zeta_j) = (Q_{uj-1} +\cdot Q_{sfj-1})\cdot(1- \zeta_j) \tag{11}$$

$$Q_{isj} = Q_{usj-1}\cdot\zeta_j = (Q_{uj-1} +\cdot Q_{sfj-1})\cdot\zeta_j \tag{12}$$

The cleaned useful products *evacuation device* is the structural block which takes over the useful product flow from the impurities cleaning system and directs it towards storage or transportation means or on the soil like windrows. Physically, the evacuation device of the cleaned useful products is composed of different types of conveyors, elevators, hoppers, platforms, slots, deflectors etc.

During the working process of the evacuation device, the processed flow of materials is not modified quantitatively or qualitatively, but only by the disposal of the cleaned useful products. Considering that the input in this structural block is the exit flow Q_{usn} [kg/s] of the n (last) successive separator of the impurities cleaning system, and the exit is the cleaned useful products evacuation flow Q_o [kg/s], it can be written that:

$$Q_o = Q_{usn} \tag{13}$$

For the general structure of the bulb or tubercle harvesting machines (see the scheme from figure 1), there can be established the expressions for exit flows, the cleaned useful products evacuation flow Q_o and the separated and eliminated impurities total flow $Q_{is\ tot}$ [kg/s], in function of the flow Q_m resulted from the digging device, if there are taken into account the individual mathematic models of the significant structural blocks and the fact that the impurities cleaning system is composed of k screen separators and l extractor separators (k + l = n), successively disposed:

$$Q_o = \left(Q_u + Q_{sf} \cdot \prod_{k=1}^{k} \xi_k \right) \cdot \prod_{l=1}^{l} (1 - \zeta_l) \tag{14}$$

$$Q_{is\,tot} = \left(Q_u + Q_{sf} \cdot \prod_{k=1}^{k} \xi_k \right) \cdot \prod_{l=1}^{l} \zeta_l + Q_{sf} \cdot \prod_{k=1}^{k} (1 - \xi_k) \tag{15}$$

Moreover, if in relation 2, is considered a sub unitary index λ, which indicates the weight of the crumbled material mass (namely with dimensions lower than the reference value) in the total mass of the mixture obtained from the digging device, it can be written that:

$$Q_u = (1 - \lambda) \cdot Q_m \tag{16}$$

$$Q_{sf} = \lambda \cdot Q_m \tag{17}$$

The index λ constitutes an indicator of the crumbling during the working process of the digging device, practically a qualitative index of the digging device. By introducing relations 16 and 17 in relations 14 and 15, and taking into account the relation 1, they are obtained the relations between the input and the outputs of the general structure of the working process of the bulb or tubercle harvesting machines, namely:

$$Q_o = Q_i \cdot \left((1 - \lambda) + \lambda \cdot \prod_{k=1}^{k} \xi_k \right) \cdot \prod_{l=1}^{l} (1 - \zeta_l) \tag{18}$$

$$Q_{is\,tot} = Q_i \cdot \left((1 - \lambda) \cdot \prod_{l=1}^{l} \zeta_l + \lambda \cdot \left(\prod_{k=1}^{k} \xi_k \cdot \prod_{l=1}^{l} \zeta_l + \prod_{k=1}^{k} (1 - \xi_k) \right) \right) \tag{19}$$

For a better understanding of the use of these general mathematical models of the variation of the materials flows during the technological process of the bulb or tubercle harvesters in concrete cases, herein after they will be analyzed three types of bulb or tubercle harvesters.

The onion digger [6] from figure 3 (to the left is presented the principia scheme and to the right a photo of this machine) is composed of: the digging device, with plane fixed blades 1, the impurities cleaning system formed of the successive rolling screens 2 and 3 and the evacuation device of the cleaned useful products, of a soil windrow forming type.

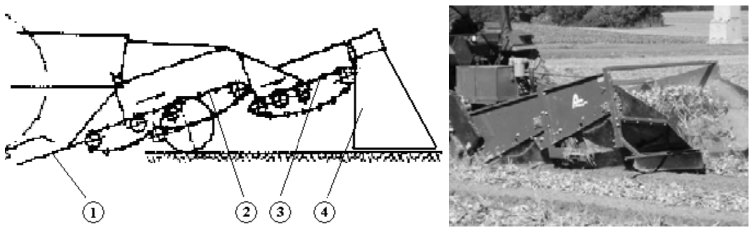

Fig. 3 Onion digger [6]

If it is considered that the digging device has the qualitative index λ, and the successive rolling screens have the precisions of separation ξ_1 and ξ_2, the expressions for the flows Q_o and $Q_{is\ tot}$ are:

$$Q_o = Q_i \cdot ((1-\lambda) + \lambda \cdot \xi_1 \cdot \xi_2) \quad (20)$$

$$Q_{is\ tot} = Q_i \cdot \lambda \cdot (1-\xi_1) \cdot (1-\xi_2) \quad (21)$$

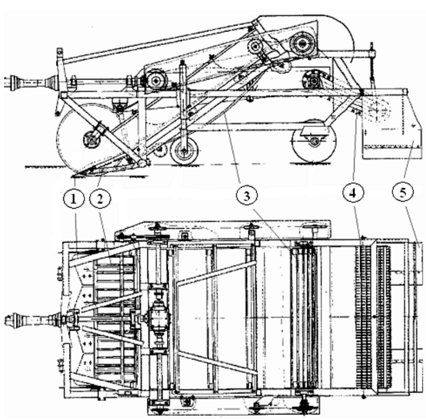

Fig. 4 Onion digger [5]

The onion digger [5] from figure 4 has the structure composed of the following significant structural blocks: the digging device, with plane fixed blades 1, the crumbling device 2, the rolling screen 3, the extractor with elastic fingers 4 and the evacuation device of the cleaned useful products, as a soil windrow forming type.

If it is considered that the digging device has the qualitative index λ, that the crumbling device has a working process which can be assimilated with a screen with precision of separation ξ_1, that the rolling screen has the precision of separation ξ_2 and the extractor with elastic fingers has the coefficient of extraction ζ,, the expressions for the flows Q_o and $Q_{is\ tot}$ are:

$$Q_o = Q_i \cdot ((1-\lambda) + \lambda \cdot \xi_1 \cdot \xi_2) \cdot (1-\zeta) \quad (22)$$

$$Q_{is\ tot} = Q_i \cdot ((1-\lambda) \cdot \zeta \cdot + \lambda \cdot (\xi_1 \cdot \xi_2 \cdot \zeta + (1-\xi_1) \cdot (1-\xi_2))) \quad (23)$$

The onion or potato digger and charger [7] from figure 5 has the structure composed of: the digging device 1, with oscillating blade fixed on the anterior side of the oscillating screen 2, the extractor 3 for the elimination of the vegetal remains, the rolling screens 4 and 5, the classifying table 6, for human operators, and the evacuation device of the cleaned useful products, as an elevator for charging in carrier vehicles.

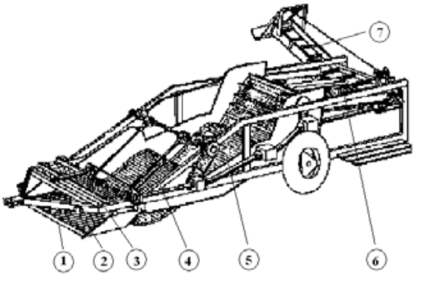

Fig. 5 Onion or potato digger and charger [7]

If it is considered that, in this case, the digging device has the qualitative index λ, the oscillating screen has the precision of separation ξ_1, the extractor for vegetal reversions has the coefficient of extraction ζ_1, the successive rolling screens have the precisions of separation ξ_2 and ξ_3 and the classifying table for human operators has the coefficient of extraction ζ_2, the expressions for the flows Q_o and $Q_{is\ tot}$ are:

$$Q_o = Q_i \cdot ((1-\lambda) + \lambda \cdot \xi_1 \cdot \xi_2 \cdot \xi_3) \cdot (1-\zeta_1) \cdot (1-\zeta_2) \quad (24)$$

$$Q_{is\ tot} = Q_i \cdot ((1-\lambda) \cdot \zeta_1 \cdot \zeta_2 + \lambda \cdot (\xi_1 \cdot \xi_2 \cdot \xi_3 \cdot \zeta_1 \cdot \zeta_2 + (1-\xi_1) \cdot (1-\xi_2) \cdot (1-\xi_3))) \quad (25)$$

CONCLUSIONS

Mathematical models of the variation of the materials flows during the technological process of the bulb or tubercle harvesters are presented in this paper. These technological flows are: *the useful products flow*, which contains the cleaned harvested products with corresponsive quality and *the impurities flows*, which are specific mainly to the different kinds of impurities separators from the harvesters structure which separate and evacuate them.

So, there are presented both mathematical models for every type of structural block of the bulb or tubercle harvesters, significant from the point of view of the technological flows variation and general mathematical models, absolutely original, for the hole technological process of the bulb or tubercle harvesters. These general mathematical models, particularly versatile, can be applied to a great diversity of constructive structures of the bulb or tubercle harvesters.

For example, in the paper, the general mathematical models were particularized for three different types of bulb or tubercle harvesters, actually in exploitation.

The knowledge of the variation of the materials flows during the technological process of the bulb or tubercle harvesters, still from the design phase, allows a precise estimation of the loading with materials of all the building blocks of the harvesters and constitutes an extremely useful instrument for the harvester designers.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.313.1:631.354
Pregledni rad
Review paper

DETERMINING THE COST MATRIX OF STRAW CEREALS COMBINE HARVESTERS, ACCORDING TO EQUIPMENT QUALITY AND ENGINE POWER

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SUMMARY

Equipment prices depend on many factors. This makes difficult the establishment as possible objective of equipment price. In order to remove this inconvenience, all the technical characteristics of a machine can be included in the notion of relative quality. Among the characteristics can be enumerated: the optimal usage time of the combine, header width, the degree of automation, etc.

The relative quality is defined as being the established quality comparative between similar entities, taking as a reference basis the entity which at the considered moment has the best characteristics. Some of the characteristics can be determined by observations or measurements but others must be determined through optimization software. In this paper is determined the costs matrix of straw cereals combine harvesters, according to the quality of the machine and power of driving motor.

Key words*: characteristics, combine, cost, optimization, quality*

INTRODUCTION

When is intended the purchase of a product must be considered certain requirements and necessities that can be met by the product. The necessities or requirements of an entity can be specified explicitly by the beneficiary or may be implicit in which case it must be identified and clearly defined. The necessities respectively the requirements are transposed into features defined by criteria as possible well-specified. The criteria should include aspects of performance, suitability for use, reliability, maneuverability, safety, ergonomics, environmental pollution and economic and esthetical considerations. The ensemble of characteristics of an entity that gives to it the ability to satisfy the needs expressed and implied, defines the quality of that [19]. The quality level represents the quality quantification through marks, points, classes, etc. It expresses the ability degree to use the product, respectively the degree of satisfaction of customer requirements.

In the specialty literature are known different methods and principles for the choice of some products [2, 13, 14, 15]. It can also be used different methods of optimization for establishing of mathematical models necessary for this purpose [1, 3, ..., 18].

In the present study is determined *the price matrix of cereal combine harvesters*, depending on *their quality* and *the engine power*.

It is known that a product may appreciate or depreciate very much over time. Therefore, the same product can have different qualities in time. In this respect, will be used the so called *relative quality*. This is established comparative between similar entities, taking as a reference basis the entity that at the considered moment has the best characteristics. The variation domain of the relative quality is considered [0, 1]. In this case, the quality levels taken into consideration can be established against the reference entity. A product of quality zero can not be used (it is considered defective), and a product with quality 1 will be considered standard.

MATERIAL AND METHOD

Establishing the quality level

The quality of a product contribute to achieving profit, whereas through its attributes increases the average productivity, being able to work continuously, without interruptions imposed by the malfunctions, of the operator fatigue or even of his illness.

At determining the level of product quality contributes all the characteristics (subassemblies) taken into account. Let x_{ai}, $i = \overline{1, m}$, the quality level of the characteristic (subassembly) *i*, of those *m* considered. The quality level of product in question is determined by the relation:

$$x = x_{a1} \cdot x_{a2} \cdot \dots \cdot x_{am} = \prod_{i=1}^{m} x_{ai} \,, \tag{1}$$

where: $x_{a1} \in [0,1]$, $x_{a2} \in [0,1]$, ..., $x_{am} \in [0,1]$.

Each quality level x_{ai} is calculated separately based on certain criteria *c*, $c = \overline{1, q}$, as good specified, corresponding to subassembly *i* considered, with the relation:

$$x_{ai} = p_1 x_{ai1} + p_2 x_{ai2} + \dots + p_q x_{aiq} = \sum_{c=1}^{q} p_c x_{aic} \tag{2}$$

where: x_{aic}, represents the quality level of subassembly *i* corresponding to criteria *c*, $c = \overline{1, q}$, *q* being the total number of criteria;

$p_c \in [0,1]$ is the weight coefficient of to criteria c from the total criteria considered. As a consequence, must be respected the condition:

$$p_1 + p_2 + \cdots + p_q = \sum_{c=1}^{q} p_c = 1 \quad (3)$$

With the above relations are calculated the quality level of considered products.

Defining of characteristics or of the subassemblies

Among the subassemblies or characteristics considered decisive, in case of cereal harvester combines, can enumerate:

1. Cutting device;
2. Beater;
3. Shaker surface;
4. Cleaning surface;
5. Power;
6. Seeds Purity;
7. Productivity;
8. Optimal time of use, etc.

Performance criteria for the cutting device:

- working width;
- type of cutting device;
- the possibility of mounting;
- easy maintenance;
- cost of cutting device;

Performance criteria for beater:

- width;
- type;
- rpm;
- the design;
- percentage of broken grains, etc.

Similarly, for each subassembly / component part of the combine can list the performance criteria which are taken into account.

An essential characteristic in the case of cereal harvesting combines is the optimal usage time. In the case of the optimum time of use, the basic criteria considered in determining the quality is the coefficient $\varphi = \frac{C_{IR}}{C_a}$, of the ratio of maintenance - repairing costs and the cost of the aggregate. The more this ratio is lower, the aggregate quality is higher and the time of use (with minimum annual expenses) is lower.

Between coefficient φ, of the report maintenance - repairing costs and the cost of aggregate in a period of 10 years, and the quality *x* of the considered entity can be establish a linking relation. Thus, it is considered that for the entity with the maximum relative quality, $x = 1$, it is known $\varphi = \varphi_{\min}$, and for an entity within the same category but of lower quality, $x = x_k$, it is known $\varphi = \varphi_k$. In this respect, considering that the variation of function φ = φ (*x*) is parabolic with the minimum in $x = 1$, will result the function:

$$\varphi = B_1 x^2 + B_2 x + B_3 \tag{4}$$

whose coefficients can be determined from the conditions:

- for $x = 1$ arising:

$$1)\ \varphi = \varphi_{\min}; \tag{5}$$

$$2)\ \frac{\mathrm{d}\varphi}{\mathrm{d}x} = 0; \tag{6}$$

- for $x = x_k$ arising:

$$3)\ \varphi = \varphi_k. \tag{7}$$

Using the conditions (5), (6) and (7), results the system of linear equations:

$$\begin{gathered} \varphi_{\min} = B_1 + B_2 + B_3; \\ \varphi_k = B_1 x_k^2 + B_2 x_k + B_3; \\ 0 = 2B_1 + B_2. \end{gathered} \tag{8}$$

The system of linear equations (8) can be solved by numerical way (Gaussian elimination method) or by analytical way.

The function φ = φ (*x*) graphically represented will be decreasing, of the form shown in Figure 1.

The values $\varphi_{\min}$, x_k and φ_k must be experimentally determined.

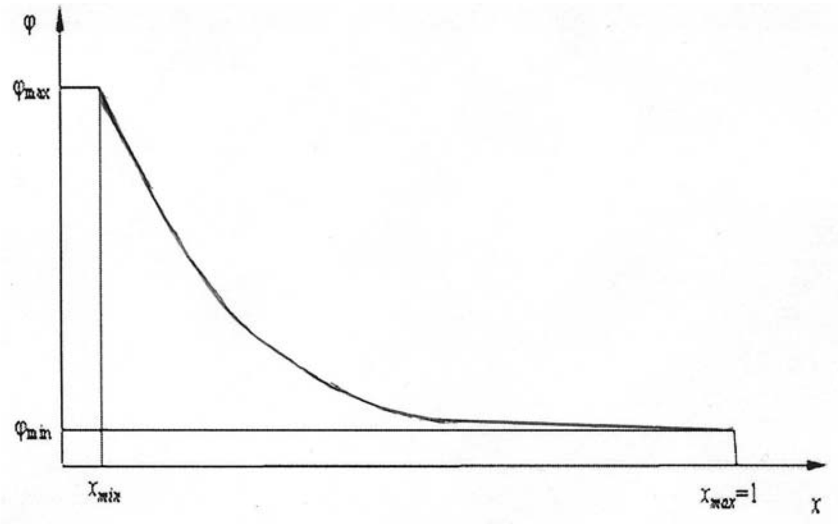

Fig. 1 Variation mode of the function $\varphi = \varphi(x)$

The optimal usage time, T_0, of the considered entity can be determined from the condition that the average of annual expenditure with the redemption and with maintenance and repairs of this, it is minimal, ie by minimizing the function:

$$C = C_1 + C_2 \tag{9}$$

where:

$C_1 = \dfrac{\delta(1+\delta)^{T_0(x)} C_a(u,x)}{(1+\delta)^{T_0(x)} - 1}$ represents the average annual cost of redemption [18];

$C_2 = \dfrac{\varphi C_a T_0^2(x)}{1000}$ represents the average annual expenditure for maintenance and repairs [14].

The function *C* resulting from the summing of functions C_1 and C_2, respectively from the summing of the function of average annual redemption C_1, corresponding to the initial aggregate cost and of the function which represents the average annual expenditure for maintenance and repairs C_2, is represented in Figure 2.

Determining the grain combine harvesters price matrix depending on the engine power and the combine quality

The combines prices vary depending on the engine power *u* and the quality of the combines *x*. Considering a large number the grain harvesters, is determined their qualities depending on the performance of various sub-assemblies or considered features.

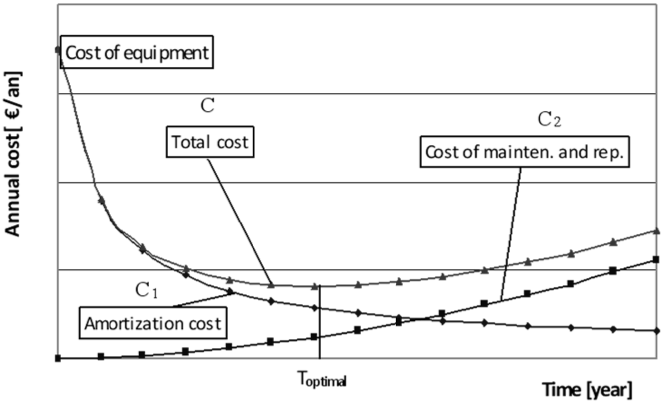

Fig 2 Determining mode of the optimal time for using of the machinery

It is assumed that the combine prices variation C_a is parabolic, of the general form:

$$f(u,x) = a_1 + a_2u + a_3x + a_4u \cdot x + a_5u^2 + a_6x^2 \qquad (10)$$

To determine the coefficients $a_1, a_2, \cdots, a_6$, it is considered six known points from the surface of prices $C_a(u,x)$, for which there are known the initial costs of those combines, namely $C_{a1}, C_{a2}, \cdots, C_{a6}$. The six points are distributed as follows:

$P_1(u_1,x_1) = P(u_{\min}, x_{\min})$; $\qquad P_2(u_2,x_2) = P(u_{med}, x_{\min})$

$P_3(u_3,x_3) = P(u_{\max}, x_{\min})$ $\qquad P_4(u_4,x_4) = P(u_{\min}, x_{med})$

$P_5(u_5,x_5) = P(u_{\min}, x_{\max})$ $\qquad P_6(u_6,x_6) = P(u_{\max}, x_{\max})$,

as shown in Figure 3.

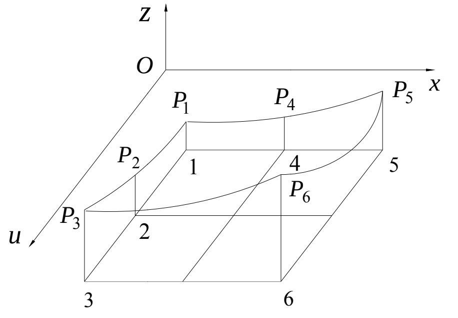

Fig. 3 Distribution of points necessary to determine the coefficients a_i, $i = \overline{1,6}$

By making replacements in the relation (10) is obtained a system of six linear equations with the unknowns $a_i,\ i=\overline{1,6}$, namely:

$$\begin{cases} a_1 + a_2 u_1 + a_3 x_1 + a_4 u_1 \cdot x_1 + a_5 u_1^2 + a_6 x_1^2 = C_{a1}; \\ a_1 + a_2 u_2 + a_3 x_2 + a_4 u_2 \cdot x_2 + a_5 u_2^2 + a_6 x_2^2 = C_{a2}; \\ \dots\dots\dots\dots\dots\dots \\ a_1 + a_2 u_6 + a_3 x_6 + a_4 u_6 \cdot x_6 + a_5 u_6^2 + a_6 x_6^2 = C_{a6}. \end{cases} \tag{11}$$

Resolving the linear equations system (11) is made through a suitable numerical method [4, 11].

RESULTS AND DISCUSSION

To obtain results as real, it is considered different power ranges of the combines engines. Examples of calculation were made for the following range of powers: 59-88 kW, 88-162 kW and 162-257 kW. In terms of quality of the combines, it is considered the range of qualities between 0.3 and 1, ie $x \in [0.3, 1]$.

Let $u \in [80, 120]$ KW, $x \in [0.3, 1]$ and $Ca \in [30000, 90000]$ €.

For the range of engine powers of the combines between 59 and 88 [kW], the qualities of these combines between 0.3 and 1, and the prices between 30,000 and 90,000 [€], the six points of the matrix required to determine the coefficients $a_i,\ i=\overline{1,6}$, will be:

Point 1 of coordinates: u=80 [kW]; x=0.3; C_{a1}=30000 [€];

Point 2 of coordinates: u=100 [kW]; x=0.3; C_{a2}=37000 [€];

Point 3 of coordinates: u=120 [kW]; x=0.3; C_{a3}=48000 [€];

Point 4 of coordinates: u=80 [kW]; x=0.65; C_{a4}=40000 [€];

Point 5 of coordinates: u=80 [kW]; x=1.0; C_{a5}=65000 [€];

Point 6 of coordinates: u=120 [kW]; x=1.0; C_{a6}=90000 [€].

Making the replacements in the system of linear equations (11), results the coefficient values $a_i,\ i=\overline{1,6}$, as follows: a1 = 51367.347; a2= -625.000; a3= -49591.837; a4= 250.000; a5= 5.000; a6 = 61224.490.

Once determined the coefficients of the function of prices, there are determined the matrix of prices for the combines comprised in the range of powers [59-88] [kW]. Similarly is determined and the matrices of prices for power bands [88-162] [kW] and [162-257] [kW].

In Tables 1, 2 and 3 presents the matrices prices of combines for power bands [59-88] [kW], [88-162] [kW] and [162-257] [kW].

Table 1 Price matrix of combines in power range 59-88 kW

	X[1] 0.3	X[2] 0.4	X[3] 0.5	X[4] 0.6	X[5] 0.7	X[6] 0.8	X[7] 0.9	X[8] 1.0
U[1]=80.0	30000	31327	33878	37653	42653	48878	56327	65000
U[2]=85.7	31592	33061	35755	39673	44816	51184	58776	67592
U[3]=91.4	33510	35122	37959	42020	47306	53816	61551	70510
U[4]=97.1	35755	37510	40490	44694	50122	56776	64653	73755
U[5]=102.9	38327	40224	43347	47694	53265	60061	68082	77327
U[6]=108.6	41224	43265	46531	51020	56735	63673	71837	81224
U[7]=114.3	44449	46633	50041	54673	60531	67612	75918	85449
U[8]=120.0	48000	50327	53878	58653	64653	71878	80327	90000

Table 2 Price matrix of combines in power range 88-162 kW

	X[1] 0.3	X[2] 0.4	X[3] 0.5	X[4] 0.6	X[5] 0.7	X[6] 0.8	X[7] 0.9	X[8] 1.0
U[1]=120.0	48000	52041	56735	62082	68082	74735	82041	90000
U[2]=134.3	50612	54816	59673	65184	71347	78163	85633	93755
U[3]=148.6	53878	58245	63265	68939	75265	82245	89878	98163
U[4]=162.9	57796	62327	67510	73347	79837	86980	94776	103224
U[5]=177.1	62367	67061	72408	78408	85061	92367	100327	108939
U[6]=191.4	67592	72449	77959	84122	90939	98408	106531	115306
U[7]=205.7	73469	78490	84163	90490	97469	105102	113388	122327
U[8]=220.0	80000	85184	91020	97510	104653	112449	120898	130000

Table 3 Price matrix of combines in power range 162-257 kW

	X[1] 0.3	X[2] 0.4	X[3] 0.5	X[4] 0.6	X[5] 0.7	X[6] 0.8	X[7] 0.9	X[8] 1.0
U[1]=220.0	80000	84694	90204	96531	103673	111633	120408	130000
U[2]=238.6	83265	88571	94694	101633	109388	117959	127347	137551
U[3]=257.1	87347	93265	100000	107551	115918	125102	135102	145918
U[4]=275.7	92245	98776	106122	114286	123265	133061	143673	155102
U[5]=294.3	97959	105102	113061	121837	131429	141837	153061	165102
U[6]=312.9	104490	112245	120816	130204	140408	151429	163265	175918
U[7]=331.4	111837	120204	129388	139388	150204	161837	174286	187551
U[8]=350.0	120000	128980	138776	149388	160816	173061	186122	200000

Diagram of variation of prices of combines in the range of powers [59-88] [kW], is presented in Figure 4.

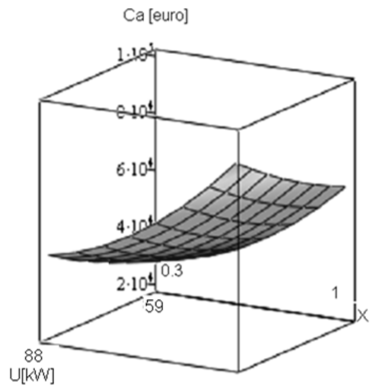

Fig. 4 Diagram of variation of prices of combines in the range of powers [59-88] [kW]

The price variation diagrams of combines in the powerbands [88-162] and [162-257] [kW], is presented in Figures 5 and 6.

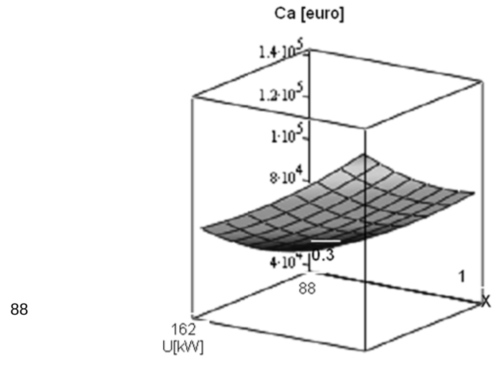

Fig. 5 Diagram variation of prices of combines in the range of powers [88-162] [kW]

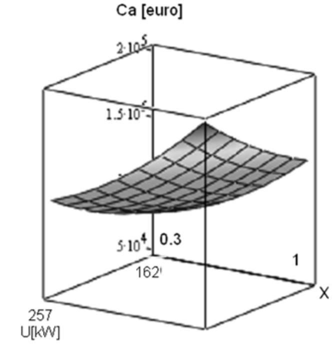

Fig. 6 Diagram variation of prices of combines range of powers [162-257] [kW]

Using the same methodology, can be determined the yields matrices of combines. Also, using appropriate relations for redemption costs of combines, maintenance and repairs, trips to plots, fuels and lubricants, and operators wages, is realised a purpose function by means of which is obtained the combine performing the considered work with minimal costs.

CONCLUSIONS

The quality of a product is a key indicator of its procurement process. In determining the product quality are taken into account all the subassemblies of which is constituted, and various characteristics of the technological process. Once established the quality of the product in different power ranges, can be establish the matrix prices in the coordinates: power, quality, cost.

In this paper were determined the matrices of prices for cereals combine harvesters powerbands of [59-88] [kW], [88-162] [kW] and [162-257] [kW]. Having regard to different parameters of technological process (working travel speeds, header width etc) can be determined and the matrix of yields. Taking into account the costs of: average annual redemption of combines, maintenance and repairs, trips to plots, fuels and lubricants, as well as the operators wages, a purpose function can be achieved by means of which is obtained the combine harvester which carried out the considered work with minimal costs.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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DETECTING NATURAL OBJECTS BY MEANS OF 2D AND 3D SHAPE ANALYSIS

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ABSTRACT

This paper describes two different approaches to detect natural objects based on their shape properties. In both cases it uses 2D snapshots of a natural scene, taken by a common digital camera. With a help of digitalized 2D images, shapes such as circles, can be identified with a help of Canny edge detector and Hough transformation, described in the first part of the paper. Canny edge detector takes a 2D image and converts it into its binarized version, revealing pixels that make up the edges of the objects. Edge pixels are then used by Hough transformation that detects prominent shapes. In the second part, the idea of 2D analysis is then taken and extended in to 3D space. It starts with 3D shape reconstruction, followed by a 3D Hough transform. 3D reconstruction enables us to transform 2D pixels into 3D voxels, which are then analysed by a 3D Hough transform.

Key words: *shape analysis, edge detection, Hough transform, multiview geometry, 3D reconstruction*

INTRODUCTION

Various approaches have been used to detect natural objects such as fruits on trees, on bushes, or on the ground, either to count them or to direct robotic arms towards them. In general, they can be classified into three groups according to the techniques used as described below.

The procedures described by the first group of authors (Sites et al., 1988, D'Esnon, 1984) are based on capturing digitalized images while applying addition lighting to the scene. The illumination conditions are selected with a care to promote regions of interest and to suppress surroundings. Some purposed approaches also use night-time conditions, when they are not interfered with other light sources. Presented solutions are therefore at least awkward and unpractical.

The second group of authors (Juste et al., 1991, Stajnko et el., 2005, Zaho et al., 2005) purpose to apply digitalized images taken by a common CCD digital camera without any artificial light sources. Images are captured under uncontrolled environments using everyday photographic equipment. In contrast to solutions from the previous section, digitalization step is simple, but detection step presents quite a challenge.

The last group of authors relays on the use of range sensors or stereovision systems, as described by Jiménez et al. (1999) and Benady et al. (1992). They offer a unique view of the scene, providing range data, where it represents measurements of distance from the sensor to the observed object. Based on range data the curvature of observed object can be determined. In case region in question has the right shapes it probably represents objects we are looking for. The process is not as straight forward as it may seem, but tends to gain on complexity as scene complexity increases.

As an example of the third group, Tanigaki et al. (2008) presented a cherry harvesting robot that works with the help of 3D vision sensor. The sensor is made up of artificial light sources and two digital cameras that enable the robot to estimate the distance between the sensor and the object by using stereovision approach. The robot is able to detect mature cherries that are picked by using 4 degrees of freedom end effector.

Similar work has been done by Van Henten et al. (2003). In their work they describe a prototype of a robot that is able to pick cucumbers. It also uses stereovision to locate cucumbers, but still faces some problems. For example, it takes at best 53 seconds to detect and harvest a single cucumber, where authors report 74.4 % success rate after several attempts.

3D sensors as well as stereovision cameras offer a unique view of the scene, but use expensive and specialised equipment that is rarely available on the field. This is the reason we decided to use images, taken by a common digital camera, in our work. Furthermore, no additional data is provided with images regarding the location and capturing conditions.

The paper describes two different approaches to detect natural objects, based on their shapes. In both cases we look for familiar circular/spherical shapes as they are most common when dealing with natural objects, such as apples, oranges, tomatoes, etc.

SHAPE ANALYSIS

Shape analysis of 2D images can be achieved in one of two ways; eider in 2D or in 3D space. In both cases pre-processing steps should be included in order to prepare an image for the final shape analysis step.

In 2D case, an image must first be colour segmented in order to detect edges that make out the shapes of the objects. By revealing the edges, its pixels can be used with a Hough transform that can confirm or reject and object based on its contours.

The 3D case starts with colour segmentation, similar to that in 2D case. Its purpose is to reveal a group of pixels that make up an object. These groups of pixels are then used in shape reconstruction, followed by a 3D shape analysis step.

The following sections describe all methods needed to understand and detect objects based on their shapes eider in 2D or in 3D space. An example case of shape verification is depicted by Fig. 1, where the left image represents an input image, the middle image represents its colour segmented version, and the right image the result of shape analysis.

Figure 1 A test example – the left image presents the original images of a natural scene, the middle image its colour segmented version and finally, the right image, the result that was confirmed 2D or 3D shape analysis

CANNY EDGE DETECTOR

Canny edge operator (Canny, 1986) is one of the most widely used edge detectors in image processing field. It is a multi-stage algorithm, developed to offer good detection, good localization and with minimal response, where edges should be correspond to real edges and not noise. In order to satisfy the requirements, Canny purposed an optimal function, described by the sum of four exponential terms.

The algorithm comprises the following steps:

- A noise reduction step; convolution between an image and a Gaussian kernel in order to reduce high frequency noise,
- An intensity gradient calculation step; based on first-order derivatives a gradient map is calculated in each direction and combined in magnitude direction map,
- A non-maxmum suppression step; the neighbours of each pixels are analysed and with a combination with gradient maps, an edge thinning is applied,
- A hysteresis tresholding based edge tracing step; used to remove week edges and to connect unconnected edges.

HOUGH TRANSFORM

In order to verify shapes that are described by their contours, we can apply Hough transform (Hough, 1962). It works by transforming an input image into parameter space, where voting procedure is carried out. Possible candidates are determined with the help of local maxima in the accumulator space defined by parameters such as radius and coordinates.

The easiest way to present Hough transform is to explain how it can be used to detect lines. The first step of detecting lines in an image is, to build a parameter space defined by line's normal form:

$$x\cos\theta + y\sin\theta = \rho \tag{1}$$

where θ is the angle of an vector pointing from the origin of the coordinate space to the closest point on the line and ρ represents its length. Each point in parametric or accumulator space, as it is also commonly referred, is therefore defined with parameters and θ and ρ, and has an initial (voting or accumulator) value of 0. For each possible pixel in spatial space, initially identified by an edge detector, a transformation to parametric space is calculated, where it reveals all possible parameters θ and ρ that could identify a given pixel. All voting locations defined by possible parameters θ and ρ are added a value of 1. This produces a 2D space of values, where local maxima reveal which parameters θ and ρ define the most prominent lines in original, spatial space.

The Hough transform for lines can be easily generalized to detect circles. Instead of using parameters θ and ρ, a parametric space can be computed using parameters from parametric form of a circle shown by Eqs.

$$x = x_0 + r\cos\theta \tag{2}$$

$$y = y_0 + r\sin\theta \tag{3}$$

where x_0 and y_0 define a centre of a circle with radius r. In contrast to line detection, accumulator space for circles is 3D as it is defined by two coordinates and a radius. As for the lines, the search for optimal circle transforms to simple local optima detection of the voting values.

The idea of detecting circles in 2D spatial space can be extended to detect spheres in 3D space. For 3D case we recommend using The Cartesian equation of a sphere cantered at the point (x_0,y_0,z_0) with radius r as given by Eq.

$$r(x,y,z) = \sqrt{(x-x_0)^2 + (y-y_0)^2 + (z-z_0)^2} \tag{4}$$

In case Hough transform is extended to detect spheres based on the parameterization of Eq., a 4D accumulator space is constructed, defined by three coordinates (x_0,y_0,z_0) and a possible radius size r. After voting procedure a global maxima is detected. In case it reaches high enough values, the spherical shape is confirmed or otherwise rejected.

3D RECONSTRUCTION FROM 2D IMAGES

Reliable corresponding points, with a difference of intensity close to zero for a given window, can be used to reconstruct selected regions in 3D space. The proposed algorithm for detecting objects of irregular shape needs a 3D reconstruction that preserves shapes. We decided on projective reconstruction and followed the procedure from Forsyth (2002) and Mahamud et al. (2001). This approach builds on the inverse projection from 3D to 2D, which can be written as follows:

$$\mathbf{D} = \mathbf{MP} \tag{5}$$

here **M** designates a camera matrix having a size of $3m \times 4$, a matrix **P** of size $4 \times n$ that stands for a matrix of 3D corresponding points, and D, a matrix of size $3m \times n$ that describes a 3D-to-2D transformation; m and n stand for the number of views and the number of corresponding point pairs, respectively. Matrices **D**, **M** and **P** have the following form:

$$\mathbf{D} = \begin{bmatrix} z_{11}\mathbf{p}_{11} & \cdots & z_{1n}\mathbf{p}_{1n} \\ \vdots & \ddots & \vdots \\ z_{m1}\mathbf{p}_{m1} & \cdots & z_{mn}\mathbf{p}_{mn} \end{bmatrix} \tag{6}$$

is composed of corresponding points of a form $p_{ij} = (x_{ij}\ y_{ij}\ 1)^{\mathrm{T}}$ and initially unknown projective parameters z_{ij};

$$\mathbf{M} = \begin{bmatrix} \mathbf{M_1} \\ \vdots \\ \mathbf{M_m} \end{bmatrix} \tag{7}$$

is a set of camera matrices that project the following 3D points:

$$\mathbf{P} = \left[\mathbf{P_1 P_2} \ldots \mathbf{P_m}\right] \tag{8}$$

The 3D points have the following form: $\mathbf{P}_t = [x_t\ y_t\ z_t]^T$. Since **M** and **P** are unknown, we cannot set projective depth parameters z_{ij} directly. Instead, we can use an iterative scheme that minimises the error between projective depths and matrices **M** and **P**, as described by Forsyth (2002) and Mahamud et al. (2001). Matrix **D** of Eq. can be factorised by singular value decomposition (SVD), and the obtained left unitary matrix will correspond to the camera projection matrices, while the right unitary matrix multiplied by singular values corresponds to the 3D reconstruction points. A weak projection estimate must be provided, an initial estimate with unknowns z_{ij} set to 1, which minimizes the error and iterates towards a global minimum, as suggested by Forsyth (2002).

2D SHAPE ANALYSIS

In order to outline the 2D shape analysis we will use an example from Fig. 1 (left image) and start with colour segmentation, where we limit our search to the following interval of hue space (Gonzales, 2001): [0.15 0.25]. The result is depicted by left image on Fig. 2.

Next, Canny edge detector is used to reveal which pixels make up the edges of the objects. The edge pixels must be detected and are used as an input parameter of the subsequent circular Hough transform. The result of Canny edge detector can be observed on Fig 2 (right image).

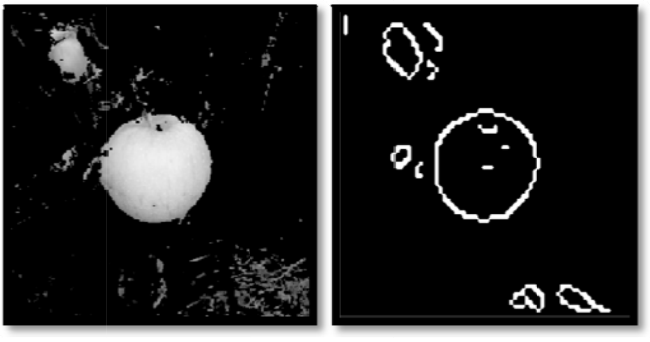

Figure 2 A colour segmented image (left) with applied Canny edge detector (right)

Based on the distribution of edge pixels an accumulator space is calculated by Hough transform. Its purpose is to reveal the radius and coordinates of an optimal circle. An example from Fig. 1 can be observed on Fig. 3 where the canter of an optimal radius is clearly visible as a bright, high enough centre peak with maximum vote count. Based on the coordinates and an optimal radius a solution can be given as depicted by right image of Fig. 3.

In case we deal with images depicting whole objects, the 2D analysis is enough, but in cases where the objects are partly occluded, the analysis might fail. In this case, it is advisable to use 3D shape analysis that reveals the missing depth information that is not affected by the partial occlusions.

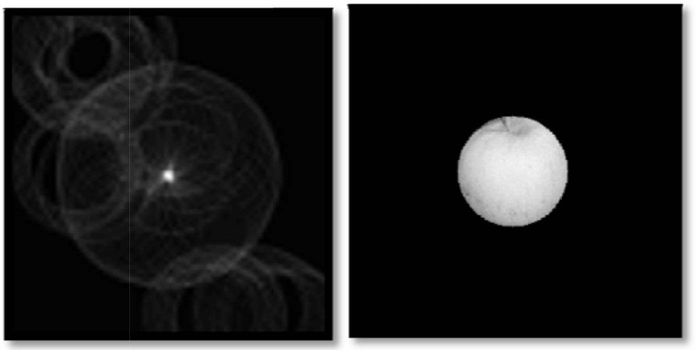

Figure 3 An accumulator space (left) and the result of circular Hough transform (right)

THE RESULTS OF 3D SHAPE ANALYSIS

In order to make 3D reconstruction and 3D shape analysis for the left image from Fig. 1 its pair must be provided as depicted by Fig. 4. Both images from Fig. 4 depict two different but overlapping views of the same scene. For a successful reconstruction corresponding pixel pairs from both images must be provided and can be detected, for instance, with RANSAC (Fishler, 1981) or image registration methods (Goshtasby, 2005). On Fig. 4 we have selected and marked with white as white pixels good corresponding pairs with possibly the right shades of colour and similar background.

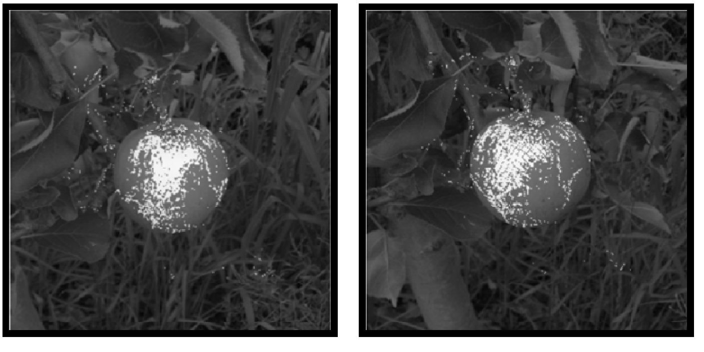

Figure 4 Detected corresponding points, marked as white pixels.

By taking a look at Fig. 4 we see that not all corresponding pairs are on the fruit surface. This is to do with colour segmentation that is rarely perfect, when dealing with green fruits against green leaves, and proves additional verification steps, such as 3D shape analysis, must be carried out.

Corresponding pixel pairs are used in 3D reconstruction step. The procedure is iterative where with each iteration the error between discrepancies in 2D spatial space and 3D projected space.

Fig. 5 depicts the result of our test example from Fig. 4. The left image depicts a set of reconstructed voxels in 3D space, while the right image includes a sphere that best fits the reconstructed voxels. The sphere was determined by calculating the circular Hough transformation (Gonzales, 2001). Based on the number of the voxels on the surface of the sphere or its vicinity we can easily conclude if it is of a nearly spherical shape and it could represent an object such as an apple of nearly spherical shapes.

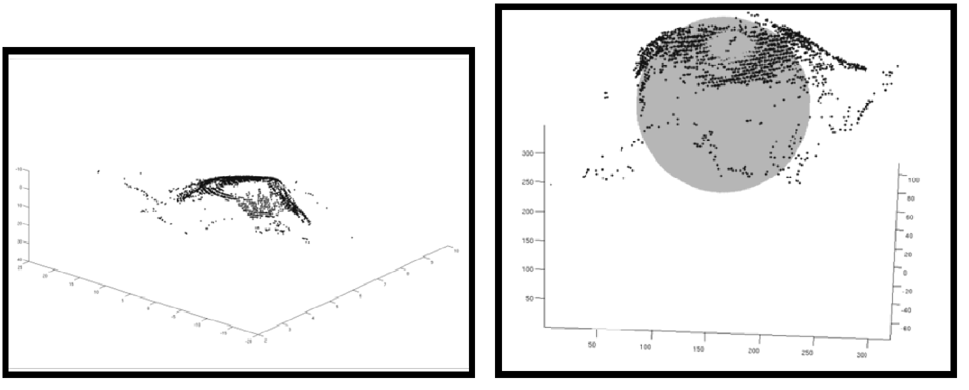

Figure 5 Reconstructed voxels for our test example from Fig. 4; the left image depicts a 2D view of the reconstructed 3D space, while the right also includes a reconstructed sphere that best fits the reconstructed voxels

Based on the outlined procedure from the previous example, 3D shape analysis was performed for 30 randomly selected examples. The examples were classified in one of four groups; the first representing colourful objects, such as yellow-red fruits against green background, the second colourful object with partial occlusions due to other objects in the scene, the third less colourful objects, such as green fruits against green background, and the fourth less colourful objects with partial occlusions. For the first group we used 7 examples, for the second 5, for the third 7 and for the fourth 5. The results for each group is summarised by Tab. 1.

For all test examples we have selected a little less than 4000 corresponding pairs, as this posed a memory restriction in our program. Next, we estimated the number of voxels that perfectly fit the reconstructed sphere and the number of voxels that lay in close proximity (± 1 voxels) of the sphere. Due to the pseudo-spherical shapes of natural objects, that are not 100 % spherical, perfect fit is not to be expected. Nevertheless, the location of the majority of reconstructed voxels of all test examples proved the reconstructed shapes describe (pseudo-)spherical objects.

Table 1 Average 3D shape analysis measurements for 30 randomly selected examples classified in to four groups

	Group 1	Group 2	Group 3	Group 4
The number of used corresponding pairs	3763 (~31 % of all fruit pixels)	3751 (~46 % of all fruit pixels)	3536 (~25 % of all fruit pixels)	3801 (~32 % of all fruit pixels)
Num. of voxels that align perfectly	577 (15 %)	416 (11 %)	386 (11 %)	151 (4 %)
Num. of voxels in close proximity (± 1 voxel)	1983 (53 %)	2076 (55 %)	1997 (56%)	2280 (60 %)

CONCLUSIONS

In this paper we presented an approach to detect natural object based on its 2D or 3D shapes. In eider case a pre-processing step of colour segmentation must be applied. Then, in 2D case, the segmentation is followed by the Canny edge detector and in 3D case 3D reconstruction. For the final step circular Hough transform is applied (2D or 3D) that helps to assess the resulting shapes. The approach could be used as a preliminary step to detect natural objects, such as apples, of the fruit prognosis system.

As we have observed in the 2D shapes analysis section, the procedure is not always the best choice, as it does not provide good enough responses in cases of party occluded shapes. This is the reason 3D shape analysis is recommended, that can be successful even if only part of the objects surface is visible. Of course 3D information is lost with capturing 2D snapshots, but it can be successfully reconstructed if one or more additional overlapping snapshots are provided.

There are many things that could be improved or added to the object detection system. For one, we have only used pairs of images and the quality of the reconstruction might further improved if we would use more. In addition, if we would combine the shape analysis with some other decision making methods, such as texture analysis, the quality of the method would even improve even further.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

A DIGITAL METHOD FOR APPLE SURFACE QUALITY GRADING

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SUMMARY

Computer assisted image analysis offers many important (pseudo) man-independent procedures, which can be used in combination with classical evaluation methods. This paper presents a novel approach in fruit surface quality analysis. It includes a computer program, based on contour recognition and decomposition of digital image objects according to their color scale intensity. This analysis has been performed by digital pattern recognition method (DPR), which is based on automatic color scale and object analysis of isohels contours for isolated and separated objects. As a result of this analysis, a more precise grading of the fruit surface quality can be achieved.

Key words: *quality control, apples, digital image analysis*

INTRODUCTION

Over the past few decades, an increasing expectation of the fruit quality control has been evidenced in developed countries. From a technological point of view, fruit quality characterization may be performed on the basis of physical as well as on the chemical properties. Most of marketing food products, which included also apples, emphasizes product attributes such as size, color and variety [1]. While some sorting processes are accomplished with optical or electronic technology, much sorting job is done by manual visual inspection. In order to ensure better sorting quality, minimize the expenses and human labor, nondestructive control methods and technical systems has been developed and applied worldwide. Fruit sorting detection systems for controlling of health condition, is based on the known phenomena that mechanical damage of the fruit influences the electrical, thermal and optical reflection properties of their surface. At present, the most commonly used technical systems are generally based on different light reflection between the healthy and damaged fruit surfaces [11]. In this approach a control device measures the optical parameters of the fruit surface, convert them into electrical signals and transform them in an appropriate digital image.

In this paper, a novel technique for fruit surface quality grading, based on digital image analysis, is introduced and presented.

MATERIALS AND METHODS

In general, digital quality analysis is based on laws of photometry (automatic CMYK, gray scale and object analysis of isohels contours for isolated and overlapped objects [2], [3]. Basic image preparation is performed by automatic interpolated resize, median, brightness and contrast corrections, while the background filtering of images is performed by Gaussian blur effect and pixel set analysis (subtract analysis for transparent layers, layer decompositions, threshold, …) of images in bit domain [7], [8].

In order to perform object analysis, digital pattern recognition method is developed (a set of standard algorithmic methods) which consists of several process [4], [6]. The first process in the digital pattern recognition of digitalized images is the determination of pseudo - rectangles polygons with 4 vertexes in 3 views (screen, image and physical coordinates of real samples), combined with determination of referent positions of polygons (polygon vertexes) on screen and creation of a set of screen coordinates of polygons. In the second stage, calculation of a set of image coordinates of polygons is performed by using file format description (I/O procedures). This way, a set of physical coordinates of polygons of the presented image is obtained. The use of library functions (for solving linear and nonlinear algebraic equations) eliminates deformities of images in the calculation process.

The second process includes determination of the gray scale and CMYK histograms of image as well as primary things-in-pattern detections (contours based on contrast-edge detection – Sobel transformation, adjustable median and threshold analysis). This process is solved by using exact contour analyzing methods, whose average decomposition speed is 1 Mpixel/s (on PC at 1GHz working frequency and 512 MB RAM).

The third process is the determination of the digitalization area and the determination of the color and gray scale resolution in decomposition of the image by using graphical user interface (GUI)). The multi layer (skin) analysis of the image and the 3D reconstruction of image depth analysis, which includes overlay effects for no isolated samples can be also used in this process.

The final process involves data acquisition, based on I/O processing and creating sets of similar patterns (FFT analysis creates numerical templates of things-in-pattern). This process determines reflection isohels of 3D objects, surface-volume analysis and the recalculation of digitized data in physical coordinates [3], [9].

Using the elements of digital pattern recognition method and the methods of data processing, several new software packages for single-fruit grading of external quality parameters have been developed [5], [10].

RESULTS AND DISCUSSION

Shape and size analysis

Shape and size analysis are based on FFT analysis of isolated isohels contours and 3D analysis in volume domain. In the size analysis process, exported results are real volumes and estimated errors of sample volumes (30 samples of apple fruit were tested in total).

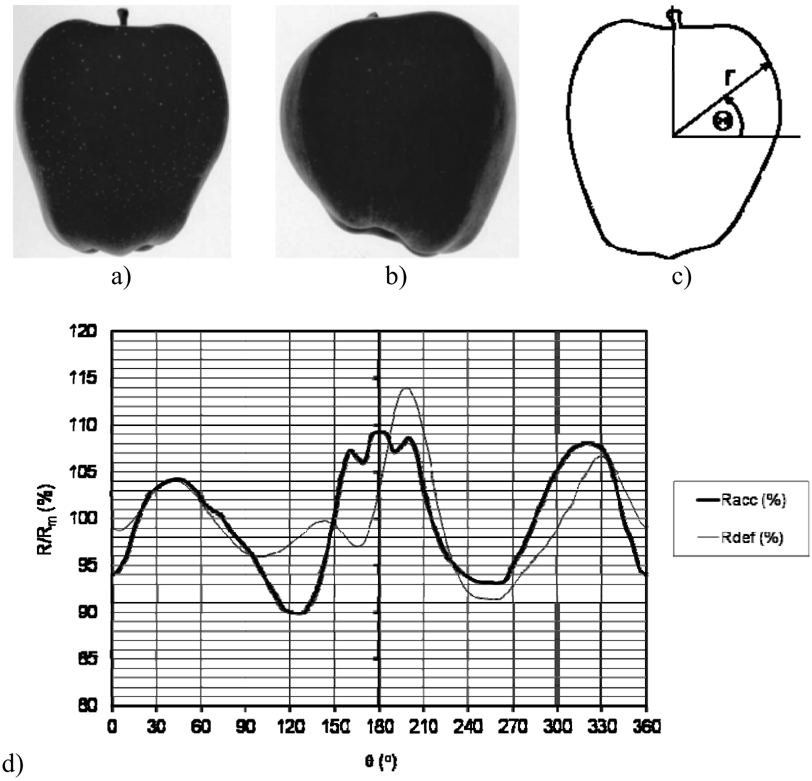

Fig. 1 Shape and size analysis of "Red delicious" a) acceptable fruit shape, b) unacceptable fruit shape, c) graphic explanation of the fruit shape and size analysis, d) eccentricity factor and estimated deviations of the sample diameter

In the shape analysis of objects exported results represent angular distribution of sample radius, complex FFT coefficients, average eccentricity factor and estimated deviations of the sample diameter. For example, a measure of the shape “quality” is so called eccentricity factor:

$$e = R/R_m * 100\ \%, \tag{1}$$

where R is the apple fruit radius defined according to Fig. 1c, R_m is the average radius of the sample shape fruit. The factor e, and the current radius R, are measured for different polar angles θ (0^0, 5^0, 10^0, ..., 360^0).

While the maximum eccentricity factor for ideal red delicious sample is up to 10 %, it reaches 14 % for deformed red delicious sample – an example is given in Fig. 1d. It can be also seen that the acceptable apple fruit shape is much closer to an ideal symmetrical profile.

Fruit damage analysis

Damage analysis has been performed (for 30 apple fruit samples) by detailed color histogram, 3D object decomposition and diameter distribution analysis of isolated objects on the sample surface. Exported results of damage analysis comprehend apple fruit sample volume, area, depth of surface vacancies and histogram spectrum. It can be mentioned that the total suspect damage surface for grade I samples according to the standards is less then 1 % of the total fruit surface, and nearly 5 % for the damaged fruit sample.

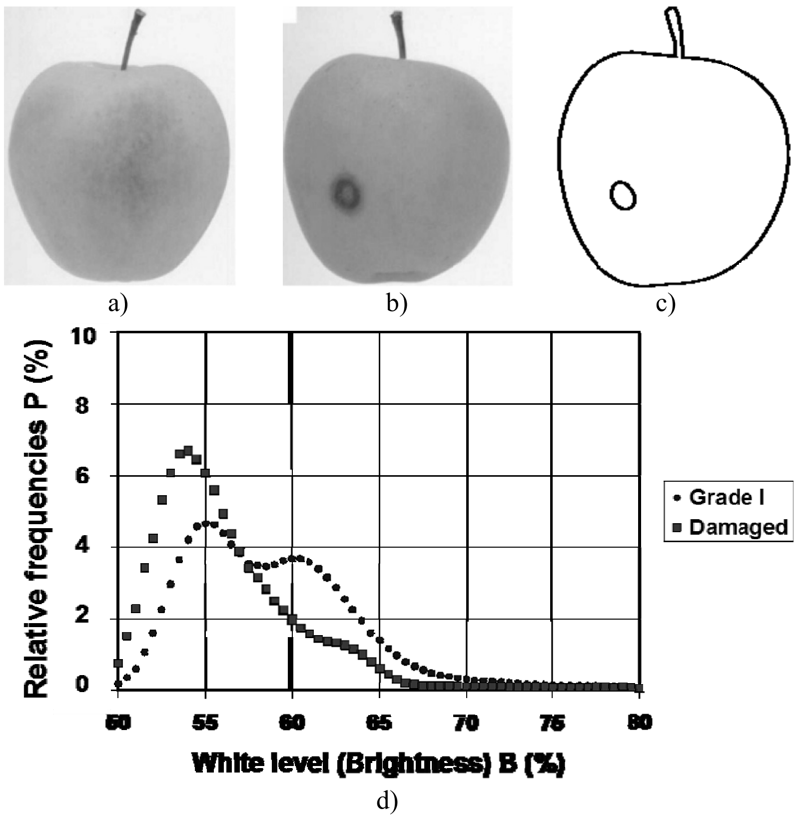

Fig. 2 Fruit damage analysis of "Golden Delicious"; a) grade I, b) damaged, c) graphic explanation of the fruit damage analysis, d) graphic analysis of fruit damage

The exported results are the brightness levels of the fruit surface digital image, converted to 256 gray scale levels. As it can be seen from an example given in Fig. 2b, fruit sample with damaged surface is characterized by larger surface area of darker gray level with respect to grade I apple fruit sample (Fig. 2a). Relative frequencies P of damaged fruit surface (red squares) have greater values at smaller (darker) brightness levels (up to B = 53.5 %) in comparison to grade I apple fruit sample. At larger values of B (which correspond to surface having higher light reflection), the grade I fruit sample is characterized with higher values of P, with respect to damaged fruit sample surface.

Russeting analysis

Russeting analysis has been performed by detailed CMYK histogram, CMYK spectrum analysis based on FFT and diameter distribution analysis of distributed objects on the sample surface. Exported results in russeting analysis are total russeting coefficients (complex FFT coefficients presented with russeting density and total russeting area), diameter distribution (average diameter, deviation of diameter) of russet spots, russeting intensity and density distributions and quality grade coefficients.

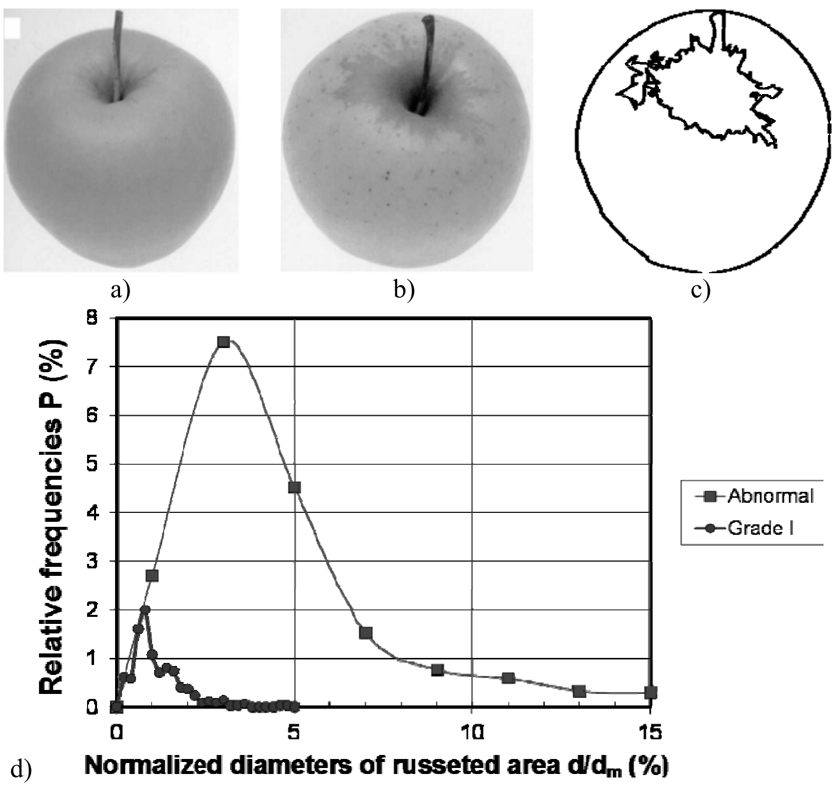

Fig. 3 Russeting analysis of "Golden delicious"; a) grade I apple fruit characterized with light russeting in the stem area, b) heavy russetted apple fruit in the stem area, c) graphic explanation of the fruit russeting analysis, d) graphic analysis of fruit russeting

As it can be seen in Fig. 3, normalized diameters of russeted area d/d_m (where d is the diameter of the russeted area in the polar coordinate system and d_m is the average diameter of the russeted area) have smaller values (up to 5 %) for the grade I fruit sample, in comparison to heavy russeted fruit sample, with d/d_m values up to 15 %.

CONCLUSIONS

In this report, new methods and procedures for digital surface analysis were presented. Programs are based on contour recognition and decomposition of digital image objects according to their color scale intensity. This analysis has been performed by digital pattern recognition method – DPR which is based on automatic color scale and object analysis of isohels contours for isolated and separated objects.

The method and successfully realized programs for surface quality analysis is presented in this paper. 3D rendering and analysis of the digitalized images have proved:

1. Relative estimated errors in image processing are less than 0.1 %, thus presented methods supports high – precision presentation of physical data;
2. Wide range of image sizes that can be processed;
3. The program supports more than 20 image filters for image input (for example: several compressed versions of TIFF, JPG, etc.);
4. The methods are able to analyze a complete image with layers in depth domain;
5. The results of the analyzing procedure have got also the estimated standard errors for any result presented in the program;
6. The program supports some image effects like manual zoom, rotate, blur, posterization and arbitrary rotation.

ACKNOWLEDGMENTS

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

SOME APPLICATIONS OF ARTIFICIAL NEURAL NETWORKS IN AGRICULTURAL MANAGEMENT

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SUMMARY

In this paper is presented a Matlab program structure for the implementation, training and use of a neural network used to predict bankruptcy. The use of artificial neural networks to predict agricultural firms' bankruptcy is extremely efficient; the prediction of accuracy percentage is higher than in the case of using traditional methods. Generally, application features remain valid in this case too, beneficial exploitation of ANN is taking place within the economic processes in which mathematical model is difficult to achieve, and too complex or the existing mathematical model has not the necessary accuracy (SUITABILITY low). The use of artificial neural networks for agricultural companies' bankruptcy prediction is extremely efficient, the prediction accuracy percentage is higher than in the case of using traditional methods; it can also be considered the existence of a data volume higher than the network training; (it is underlined that the training sessions were made for a set of 56 companies, but for the result check were used 120 companies).

***Key words**: financial management, artificial neural networks, agricultural management, financial optimization*

INTRODUCTION

Forecasting has been called both an art and a science. It is an ability to recognize patterns through a logic analytical approach. With today's forecasting techniques, managers are able to understand the future better than managers of past eras. Prediction of bankruptcy has long been an important topic and has been studied extensively in the accounting and finance literature. [5]

In using neural networks, the entire available data set is usually randomly divided into a trening (in-sample) set and a test (out-of-sample) set. The training set is used for neural network model building and the test set is used to evaluate the predictive capability of the model. [3]

Artificial Intelligence (*AI*) can be regarded as that part of informatics that aims to design those systems that are endowed with certain properties that we normally associate with human intelligence: language understanding, learning, reasoning, problem solving, theorems' demonstration. Different definitions of artificial intelligence focus differently, either on cognitive processes or behavior. [12] Thus, *AI* can be regarded as the study of systems which:

- think like people do;
- think rationally;
- act like people do;
- act rationally.

In this paper is proposed the use of methods (paradigms) specific to artificial intelligence in financial agricultural farm management, aiming at finding some pairs {artificial intelligence method, financial management problem} in which the results have to be optimal and better than traditional methods. [6]

Under the name of "expert system" are those knowledge based on artificial intelligence programs or device of high level, comparable with the most competent experts in an application field and where, these programs can achieve thinking and intuition performances similar to human experts. "Expert system" term is used with the same meaning as "knowledge-based expert system", being preferred because of its easier pronunciation. Software development was done using Exsys Corvid expert system. The paper will use in concrete a Matlab program structure for the implementation, training and use of a neural network used to predict bankruptcy in agricultural farm. [9]

THEORETICAL APPROACH

Among methods and paradigms specific to Artificial Intelligence, expert systems are most "well-known", being the first which were imposed in practice, overcome the theoretical research framework, in author's appreciation, the avant-garde character, novelty, unconventional feature of expert systems is somehow obsolete, the membership to "artificial intelligence" field being in this moment questionable. [11]

The reasons of this chapter in the present paper, taking into consideration the innovations and the author's original contribution are significant, and are the followings:

- uniformity and minimum claim of completeness of the paper;
- design some hybrid systems, in which expert systems are a component;

The studies regarding the behavior of financial rates at the bankrupt companies are datet back almost seventy years. However one of the initiators is considered Beaver. He studied based on univariate analysis, the financial situation of a sample of 79 non-bankrupt firms.

Beaver was supported in his study on the concept of cash flow:

- The larger the reservoir, the lower the probability of bankruptcy.

- The higher the workflow, the lower the probability of bankruptcy.
- The greater the flow of operational costs, the greater the probability of bankruptcy.
- The greater the amount of debt, the greater the probability of bankruptcy.

Based on these ideas, the average values of five financial rates differ significantly from bankrupt companies group to non - bankrupt companies group. [5], [7]

The question arises how efficient it is the use of neural networks in those types of applications that fully exploit the advantage of their specifics, obviously there are types of problems that almost perfectly folded using ANN, but other types that generate even incompatibles with them. Within this chapter were introduced basic concepts specific to use ANN, following to be repeated and developed within the present chapter together with examples and study cases related. Generally based on experience in the field can be said that ANN are used in those types of problems with the following features:

- Mathematical model of the process is unknown, has too much complexity associated with insufficient accuracy (precision) and in some cases can not be determined;
- Available data are incomplete in some cases, there are signals and noise disturbance (noise term can be extrapolated from technical field and in other types of economic, genetic processes, etc.);
- There are a number of constraints (restrictions) applied to the process and have to be optimized simultaneously.

METHODS

For this study it was used a *MATLAB* program structure for implementation, training and use of neural networks used to predict agricultural farm costs.

It is proposed a comparison between methods called by the author as traditional (classical, conventional in the sense of their using and knowledge for several decades) and specific methods to artificial neural networks use. There are presented the theoretical grounds of the two methods, and gradually the results obtained after processing the same set of initial data, obviously it have been chosen the same initial data in order to make possible the comparison between the two methods, especially in terms of predicting accuracy. [5], [1], [8]

In this paragraph is presented the source text of the program, as well as the meanings of instructions and their correlation with economic context of the issue.

…

```
% enter code
clear all
close all
clc

% input data for network training
```

```
X1= [1512   1595   1440   1722   1843   1655   1903   1552   1626
        1525   1653   1498   1810   1701   1900   1605   1801   1689
        1581   1781   1827   1738   1854   2034   1909   1853   1512
        1595   1440   1722   1843   1655   1903   1552   1626   1525
        1653   1498   1810   1701   1900   1605   1801   1689   1581
        1781   1827   1738   1854   2034];

X2= [600    620    620    680    680    675    685    690    630
        632    645    634    662    670    689    612    628    677
        692    700    725    736    750    761    780    765    600
        620    620    680    680    675    685    690    630    632
        645    634    662    670    689    612    628    677    692
        700    725    736    750    761];

X3= [0.8    0.8145  0.7    0.86   0.9    0.81   0.9211  0.68980.8412
        0.78   0.8403  0.7208  0.9577  0.7955  0.8897  0.8415  0.9554  0.7888
        0.6893  0.8    0.8    0.72   0.7547  0.8804  0.8    0.7398  0.8
        0.8145  0.7    0.86   0.9    0.81   0.9211  0.6898  0.8412  0.78
        0.8403  0.7208  0.9577  0.7955  0.8897  0.8415  0.9554  0.7888  0.6893
        0.8    0.8    0.72   0.7547  0.8804];

X4= [0.9    0.9307  0.8894  0.7812  0.9    0.7915  0.9302  0.8109  0.8792
        0.8113  0.8597  0.8905  0.8107  0.9343  0.9755  0.9281  0.955  0.8951
        0.8637  0.93   0.9    0.8905  0.95   0.9    0.81   0.9222  0.9
        0.9307  0.8894  0.7812  0.9    0.7915  0.9302  0.8109  0.8792  0.8113
        0.8597  0.8905  0.8107  0.9343  0.9755  0.9281  0.955  0.8951  0.8637
        0.93   0.9    0.8905  0.95   0.9];

X5= [66.14  62.69  69.44  58.07  54.25  60.42  52.55  64.43  61.5
        65.57  60.49  66.75  55.25  58.78  52.63  62.3   55.52  59.2
        63.25  56.14  54.73  57.53  53.93  49.16  52.38  43.17  52.91
        50.16  55.55  46.46  43.41  48.34  42.09  51.55  49.2   52.46
        48.4   53.4   44.2   47.03  42.11  49.84  44.42  47.36  50.6
        44.92  43.79  46.03  43.15  39.33];

% target for input data values
T=[387.37   382.27  392.19  375.47  369.84  333.27  321.78  339.12  334.84
        340.79  339.08  348.32  331.37  336.58  327.51  305.83  295.96  301.3
        307.16  296.84  280.67  284.79  279.49  272.44  277.21  307.68  324.08
        319.47  328.52  313.22  313.86  316.38  305.83  321.8   317.84  323.32
        321.82  324.91  309.42  269.07  260.79  273.79  264.69  269.62  275.1
        265.52  263.62  267.39  262.55  256.13];

P= [X1 ; X2 ; X3 ; X4 ; X5 ; X6 ; X7 ; X8 ; X9 ; X10 ; X11 ; X12 ; X13 ; X14 ; X15 ; X16 ;
X17];
pr=minmax(P)
```

```
% creation of a feedforward network type
net1=newff(pr,[1150 1],{'tansig', 'purelin'},'traincgf');
net1.trainParam.lr=20;
net1.trainParam.mc=0.5;
net1.trainParam.min_grade=1e-10;
net1.trainParam.show=1;
net1.trainParam.epochs=60;
net1.trainParam.goal=1;

% network training
[net1,tr1]=train(net1,P,T);

% network testing with data used in its practice (X1...X17)
yantr=sim(net1,P);

% writing in exit_training.txt file of network targets for
% practice values (Y) compared with desired target in training
% (T), percentage errors for each case (Er), as well as for % average errors.
ex_train=fopen('exit_practice.txt','w');
s_er=0;
fprintf(ex_train,' Y | T | Er\n');
for i=1:1:50
 er(i)=100-((yantr(i)/T(i))*100);

fprintf(ex_train,'%4.2f\t%4.2f\t%2.2f\n',yantr(i),T(i),er(i))
 s_er=s_er+er(i);
end
if s_er<0 s_er=s_er*(-1);
end
fprintf(ex_train,'\nAverage error is %2.2f',s_er/50);
fclose(ex_train);

% data uploading from input.txt file
Q=load('input.txt')

% target calculation for the data from input.txt file
rez=sim(net1,Q);

% target writing in exit.txt file
exit=fopen('exit.txt','w');
for i=1:1:size(rez)
fprintf(exit,'%4.2f\n',rez);
end
fclose (exit)
% exit code
```

Thus, it is defined gradually the 17th –dimensional vectors (X1, X2, X3, X4, ... X17) each with 50 components, corresponding to 50 employees in one agriculture farm used to network training; those 17th vectors are corresponding to the four input variables used and namely:
the 17th vectors were included in a matrix type structure (pattern) P = [X1 X2 X3 X4...X17];
X1 – total number of employees;
X2 – number of news employees in the last year.
X3 – the average percentage of employees remaining in the second year for working;
X4 – the average percentage of employees remaining in the third year of working;
X5 – the average remunaration for manager job;
X6 – the average remuneration for the engineer job;
X7 - the average remuneration for the economist job;
X8 – the average remuneration for operator job;
X9 – the percentage share of manager jobs;
X10 – the percentage share of engineer jobs;
X11- the percentage share of economist jobs;
X12- the percentage share of operator jobs;
X13 – the average remuneration for the staff;
X14 – cost level for material base (per employee)
X15– the average cost for electricity;
X16 – the average cost per cubic meter for water and heating;
X17 – the average cost for Internet.

Further, T (target) vector is defined, obviously used, only in case of trening phase, vector which memorise the real situation in case of 50 employees under discussion. Newff instruction is used in order to create a feedforward ANN; its syntax is the following:

Net1 = newff [pr, [2 25 1], *{'tansig' 'purelin' 'purelin'}*, '*traincgf*'); in which:

Pr = min max (P), represents encoding matrix for minimum and maximum values for input variables;

[2 25 1] – dimensions (numbers of neurons) for hidden layers (in this case two with 2 and respectively 25 neurons) and obviously a neuron for output layer, corresponding to the actual cost.

Tansig and *purelin* are functions used in transferring.

Trainlm and *traincg* are functions used for training; in the framework of the train function can be set parameters specific to training session as follows:

Epochs – the maximum number of training epochs (successive resumption of training session with the same input data for several times);

Goal – the precision with which the 0.01 target result is reached, representing, for example, an error of 1%.

Time – maximum time of training in seconds;

Min_grad – minumum performance gradient;

Show – the number of epochs between two successive views of training session development;

By using train and sim functions is achieved the network training itself, for the purpose of learning its features (basically is determined the weight coefficients wij).

In the second phase is proceeded to the actual operation of the program; so it is defined and initialized the 17th input vectors, *X1, X2, X3, X4, ... X17*, each containing data of the second set of skills, considered for use, namely network check. Because within this period is done and checked the ANN data prediction accuracy, is also defined Y vector and the real values of each employee’s situation.

Determined network data will be memorised in network prediction.txt file opened with fopen function. Finally, the network use results are tabulated, the rightmost columns of the table having the following meaning:

Ynetwork – the prediction made by every network;

Yreal – representing the real situation.

Accuracy – by comparing *Ynetwork* and *Yreal* columns is displayed in the last column the accuracy of prediction. In the end it is presented the percentage accuracy of prediction, being in fact the main parameter of ssessing prediction results.

Now it can present an ANN structure and parameters optimization training in order to increase prediction accuracy of agricultural farm costs.

The purpose is that of improving prediction accuracy by optimizing ANN structures of the various parameters specific to ANN and to parameters of training.

It is estimated that it is one of the most difficult problems in the implementation and use of ANN, in many works being considered an art; increased difficulty of this problem is the large number of parameters that can be changed, some of them can not even be quantified, so the choice of the network structure (topology) and chosen training method is about the experience in the field of user, experience that have to be gained by applying the ANN to the most varied cases.

Further will be presented in the author's opinion the main parameters that could compete to optimize the prediction, being removed from the beginning ("*in common sense*”) those considered irrelevant. Obviously it requires a statistical study, using specific methods of removing the relevant parameters:

- Network topology (spread before perception, radial ...)
- Learning method;
- Non-linearity adopted function;
- Number of hidden layers;
- Number of neurons in each layer;
- Number of training epochs.

If each of the six factors considered aprioristic determinants would be considered only four different levels and would not make additional replicas for a given level of required parameters would be 46 = 4096 experiments, and therefore would be required the use of statistical methods for planning the experiment.

Within this paragraph will be presented a first organizing of the experiment, being elaborated a quasi-empirical planning, followed by a developing of the first set of preliminary conclusions. There are displayed in the tables, obtained experimental results, indicating that generally have been made three replicas (the successive experiments for each line were kept the same with input parameter values).

RESULTS AND DISCUSSION

It can make an (scientific) analysis and synthesis of experimental data obtained using artificial neural networks. After processing the results, according to previously mentioned algorithms were achieved the following drawings.

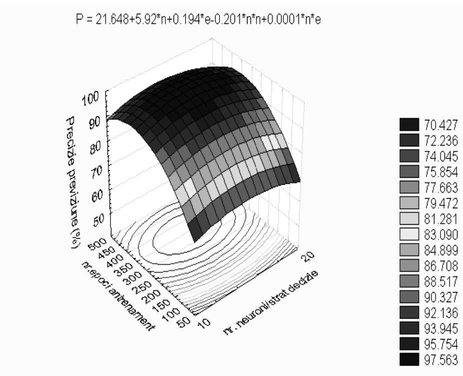

Figure 1 Prediction accuracy

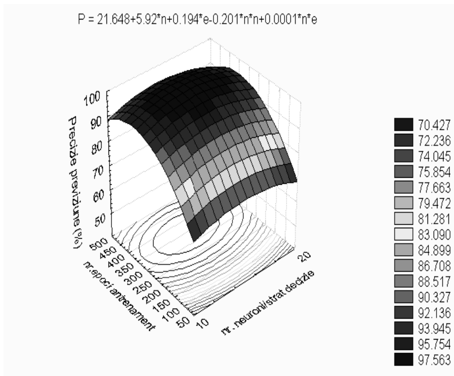

Figure 2 Prediction accuracy

Figure 1 and *figure 2* present graphically and in an objective way the function variation (percentage accuracy of prediction), according to the two variables considered in this first phase the number of training sessions and number of layers, more than even applying the method of least squares for the experimental data was obtained a second degree model to predict the following type:

$$Prec = 43.543 + 11.501 * s + 0.182 * e - 1.542*s2 + 0.002s*e, \quad (1)$$

Mainly *Fig. 1* and *Fig. 2* are identical, but differ in the reference z axis, corresponding to predict accuracy, in *Fig. 1* the origin is considered at 0% and in *Fig. 2* at 50% level.

Fig. 3 represents the result distributions. *Fig. 4* illustrates graphically and comparative the performance objective function evolution depending on the number of training epochs, the number of layers is considered as the parameter.

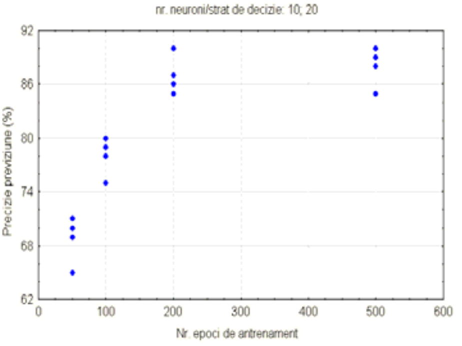

Figure 3 The result distributions

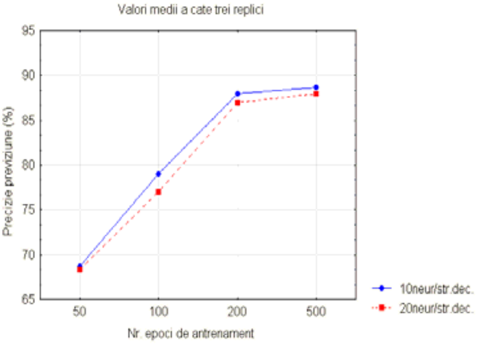

Figure 4 The performance objective function evolution

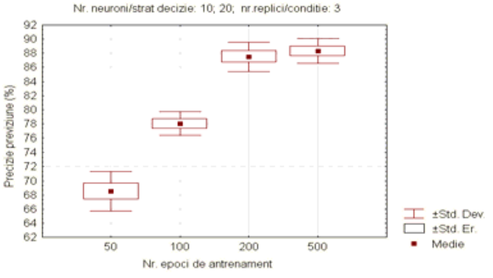

Figure 5 Statistical quantities used in undertaking research

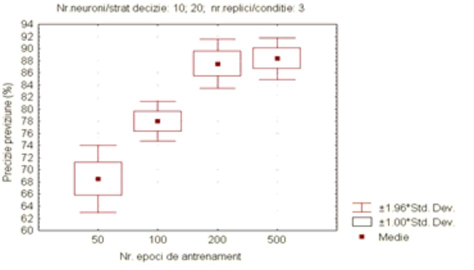

Figure 6 Statistical quantities used in undertaking research

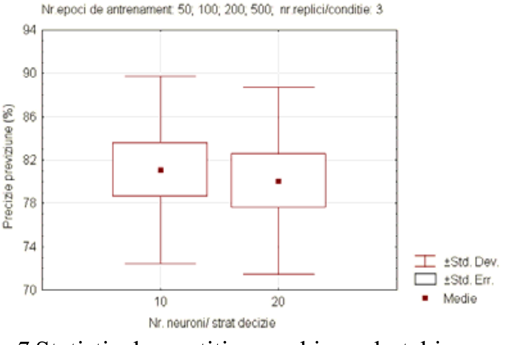

Figure 7 Statistical quantities used in undertaking research

Fig. 5, Fig. 6, *Fig. 7* are graphically presented the most remarkable statistical quantities used in undertaking research using the following conventions of representation:

- Point marks the average position;
- Rectangle marks the standard error;
- The difference between the two horizontal segments marks the standard deviation.

CONCLUSIONS

This quasi-empirical methods used for the agricultural management, special for farm level, help modernize and streamline them.

In certain situations, for example the use of artificial neural networks, has been found an exceptional applicability of those in economic field, fitting in the specifics of the economic data and processes: mathematical models of many economic processes have a high complexity associated with an insufficient accuracy and that available data are incomplete in many cases, there are disturbing signals, so for example: Percentage accuracy predictions of companies' bankruptcy were 93-97% higher than those obtained by traditional methods.

In other situations, for example in genetic algorithms case has been found a less efficient application of those in financial field; however their specific techniques could be used in case of some hybrid intelligent systems, helping to optimize other specific artificial intelligence methods.

The application of neural networks has been reported in many recent studies of bankruptcy prediction. However, the mechanism of neural networks in predicting bankruptcy or in general classification is not well understood. Without a clear understanding of how neural networks operate, it will be dificult to reap full potentials of this technique. This paper attempts to bridge the gap between the theoretical development and the real world applications of ANNs.

The use of artificial neural networks for agricultural farm costs prediction is extremely efficient, the prediction accuracy percentage is higher than in the case of using traditional methods; it also can be considered the existence of a data volume higher than the network training; (it is underlined that the training sessions were made for a set of 50 employees).

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Notations:

AI - Artificial Intelligence

ANN - Artificial Neural Networks

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

USE OF THE ECHO MONITORING SYSTEM FOR ENVIRONMENTAL CONTROL IN CONVENTIONAL AND ORGANIC PIG FACILITIES

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SUMMARY

*A total of 66 fattening pigs ([*Landrace×Large White*]*×Pietrain*) housed in a pig research centre (Faculty of Agriculture and Life Sciences, University of Maribor) were used in a study of the ability of the ECHO monitoring system to control the microclimatic conditions and gas emission rates in organic and conventional rearing systems. With the monitoring system, we were able to achieve optimal microclimatic conditions for fattening pigs. Ammonia emission in the conventional rearing group reached 17±7g pig^{-1} day^{-1}. A lower ammonia emission of 7±1 g pig^{-1} day^{-1} was found from the organic group. Higher ammonia values in the conventional group could be a result of differences in the pigs' excretory behaviour. In both rearing systems, ammonia emissions were below the maximum level listed by the International Commission of Agriculture Engineering. This experimental result suggests that with the ECHO monitoring device we are able to control and successfully regulate microclimatic conditions and gas concentrations in organic and conventional pig facilities.*

Key words: *monitoring system, microclimatic conditions, ammonia, pigs*

INTRODUCTION

Organic legislation of pig production includes a limit on ammonia emission (EC, 889/2008). Higher ammonia emissions could have negative effects on the environment (Pain et al, 1997), human health (Urbain et al., 1994) and the health of pigs (Gerber et al., 1991).

In order to achieve appropriate microclimatic rearing conditions and ammonia concentration inside pig facilities, they need to be monitored and regulated. Fully automatic computer systems that monitor microclimatic conditions as well as control ammonia concentrations are expensive and inappropriate for small pig units; however, cheaper mobile systems which monitor microclimatic conditions, gas emissions, and light intensity may be selected. This information is necessary for breeder decisions about adjusting microclimatic conditions in organic or conventional pig units.

The aim of the present study was to determine whether a mobile monitoring system, ECHO, is suitable to detect and regulate microclimatic conditions in a small pig unit. Therefore, several microclimatic characteristics and ammonia concentrations were determined in conventional and organic pig facilities.

MATERIAL AND METHODS

Animals and feed

The experiment was conducted on 66 pigs, progeny of Landrace×Large White dams and Landrace×Pietrain sires, divided into two groups. The conventional group of 33 pigs was reared according to conventional practices (UL RS, 2007), while the organic group (n=33) was reared according to standards of EU organic legislation (EC, 889/2008). During this research, lasting from 11^{th} to 26^{th} week of age, no health problems occurred. Throughout the experiment pigs had access to feed in the form of pellets. The pigs were weighed individually at 11^{th} and 26^{th} week of age. Daily gains were calculated from these two weights.

Table 1 Number of pigs per pen and area available per pig indoors and outdoors

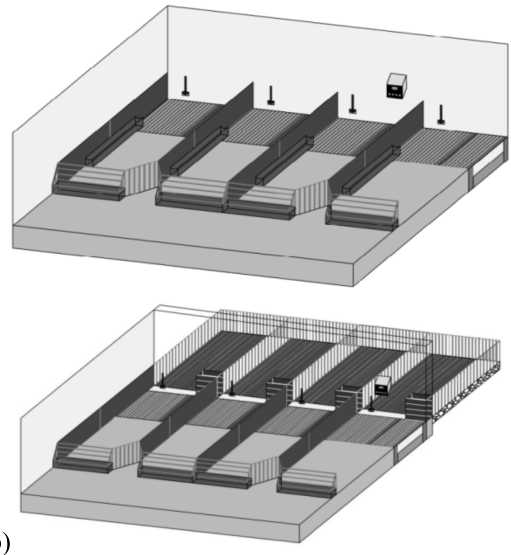
	Pigs per pen		Indoor area, m^2 pig^{-1}		Outdoor area, m^2 pig^{-1}
	CON	ORG	CON	ORG	ORG
Fattening	11	5 or 6	0.7	1.3-1.6	1.1-1.3

Animal facilities

The investigation was conducted in the Pig Research Centre at the Faculty of Agriculture and Life Sciences (University of Maribor, Slovenia). Conditions specified by national legislation on animal protection (UL RS, 2007) were met. In the present study, identical fattening facilities for both housing systems were used. Throughout the experiment, pigs were kept in groups with the inside area available for feeding, lying down, and excretion. In addition, organic pigs also had an outside area available for exercise. The layout of the rearing system is shown in Fig. 1.

Fattening facilities with an area of 86 m^2 and a volume of 206 m^3 were used for each group. The total pen area of 7.9 m^2 had two-thirds concrete floor and one-third slatted floor (Fig. 1a, b). Pigs were fed in a feeder trough that was 3.7 m long for the conventional group and 2.0 m for the organic group. Drinkers were positioned above the slatted floor.

The slurry pit was 2.0 m deep and was emptied two weeks before the experiment began. In the experiment, a negative pressure ventilation system with a diffuse ceiling inlet unit was used. The system had one central exhaust unit with ventilator, located at the roof of the house. In this ventilation system, fresh air came into the attic through the side inlet units and into the room through the diffuse ceiling inlets.



a)

b)

Fig 1 Conventional (a) and organic (b) fattening facilities

ECHO monitoring system

The ECHO monitoring system (http://www.echo.si/) was used to measure concentrations of oxygen, ammonia, hydrogen sulphide and carbon dioxide in the air. In addition, temperature, air velocity, air pressure, relative humidity, and light intensity were measured. All values were displayed on the LCD screen on the computer and they could be controlled manually. All parameters were also stored in an internal hard drive every 5 min: those values could be transferred through a RS-232 connection to the computer and monitored subsequently (Fig. 2.).

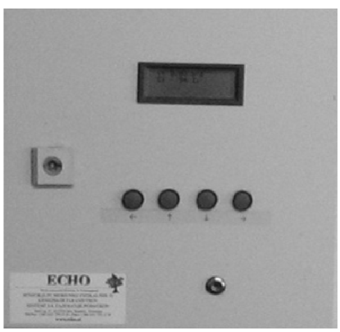


Fig. 2 ECHO monitoring system

Ammonia concentration

Ammonia concentration and emission were measured using an electrochemical galvanic cell. The measuring range was 0-25 ppm, with measurement accuracy of 1 ppm. The level of ammonia was determined with a sensor fitted with metal and air electrodes. Zinc was used as the anode, and active carbon in contact with oxygen from the air was used to determine gases (Fig. 3). Gases from the air reacted when they reached the cathode and formed hydroxyl ions, which migrated into the zinc to form zincates (Zn + 4 OH), as shown in Equation 1. Simultaneously, the electrons were released and migrated to the cathode. Eventually, zincates decayed into zinc oxide, and water returned to the electrolyte. The water and hydroxyls from the anode were recycled, so the water was not used.

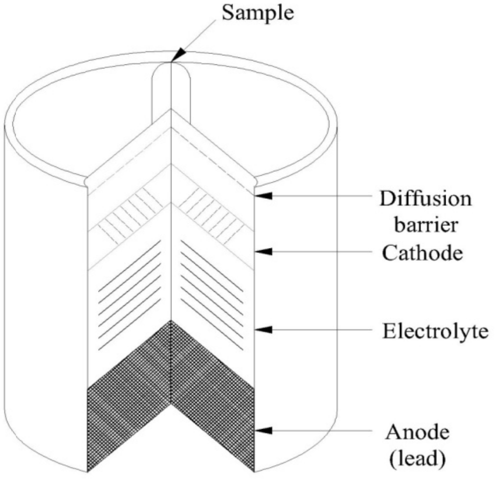


Fig. 3 Sensor for measuring oxygen, ammonia, hydrogen sulphide

Air velocity, temperature and relative humidity

Air velocity was measured using a thermal thin-layered detector that was connected via a 5 m electric cable to the computer. The detector was placed at pig height to measure the airflow. The air velocity measuring range was 0.0-1.0 m/s, with a measurement accuracy of 0.04 m/s. Relative humidity was measured using a semiconductor sensor with a measuring range of 0-100 % and accuracy of ±1 %. Temperature was measured with resistance thermometers (Pt 100), with a measured range of −40 °C to +60 °C and accuracy of 1 °C. Sensors for relative humidity and temperature were located in the mid-lower side of the machine, while the air velocity detector was situated at the bottom of the machine.

Statistical analysis

The data were analysed using the GLM (General Linear Model) procedure by SPSS 20 (2011) statistical package. The effect of rearing system was included in the model. Mean ($\bar{x}$) values with standard deviations (SD) are presented.

RESULTS AND DISCUSION

Microclimatic condition

Microclimatic characteristics that were monitored and controlled throughout the experiment are presented in Table 2. At the beginning of the research (11th week of age), the indoor temperature in the pig facilities was around 22°C. In this period, an additional heating system was required. Gradually, the ambient indoor temperature in the pig units decreased 3 to 5°C and reached approximately 19°C. No differences in ambient temperature were observed between groups. Results from the present study are in agreement with data from previous studies, where optimal indoor ambient temperature in facilities for fattening pigs was between 15 and 20°C (McFarlane and Cunningham, 1993; Olsen et al., 2001).

It is well known that the pigs' body weight is strong correlated with their heat production (Saha et al., 2010). The pigs' body temperature should remain within certain limits to safeguard welfare and maintain production (Rinaldo and Le Dividich, 1991). Therefore, the ventilation rate was adjusted in the pig fattening facilities to reach optimal microclimatic conditions. The ventilation rate was adjusted manually. Relative air humidity was between 62 and 65%, which was within the regulatory values of 60 to 80 % (UL RS, 2007). No differences in relative humidity between rearing groups and rearing phases were observed (Table 2). Pigs were kept in buildings with a combination of natural and artificial lights. Lighting intensity was above 40 lux for 8 h per day, and it was in agreement with the Slovenian law for animal protection (UL RS, 2007). No differences in air velocity between investigated groups were observed (Table 2). It has been reported that optimal air velocity at pigs' height is around 0.15 and 0.28 m/s if optimal temperatures for fattening pigs are provided (Verstegen et al., 1987**.** Our results are in agreement with these recommend-ations.

Table 2 Means and standard deviations of microclimatic characteristics throughout the experiment

Items	CON	ORG
Relative humidity, %	65 (3)	64 (2)
Ambient temperature, ºC	19.1 (0.5)	19.3 (0.9)
Outdoor temperature, ºC	6.8 (1.7)	
Pressure, bar	989 (17)	992 (11)
Air velocity, m/s	0.3 (0.5)	0.2 (0.1)
Light intensity, lux	122 (14)	126 (16)
Ventilation rate, m^3 $pig^{-1}h^{-1}$	87.6 (2.8)^c	86.3 (2.0)^c

In this optimal microclimatic condition, no difference in final body weight between conventional and organic pigs (96.6 kg *vs.* 94.9 kg) was found (Fig. 4). In the present study organic pigs had higher growth rates compared to conventional pigs (735 vs. 708 g/day, respectively). Growth rate in present research was higher than presented in the study of Ferguson and Theeruth (2002), where fully controlled systems were used.

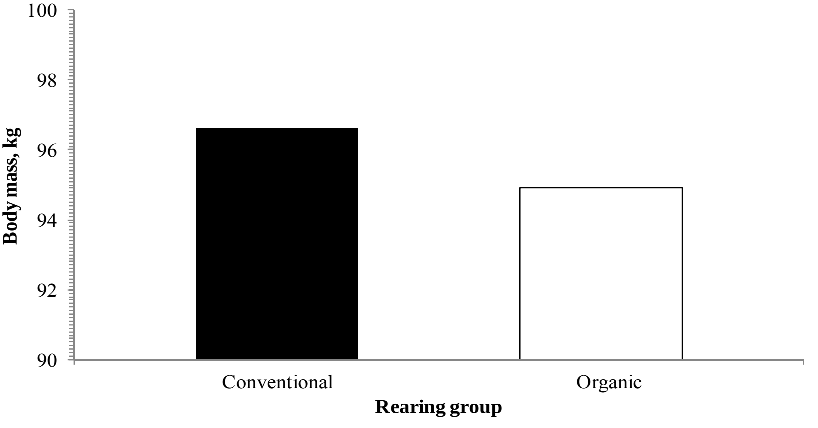


Fig. 4 Differences in final body weight between rearing systems

Ammonia emission

Urine is the main source of nitrogen that is being excreting by pigs (50 %), while faeces contain about 20 % (Jongbloed and Lenis, 1992). Nitrogen from faeces is also less susceptible to rapid decomposition (Canh et al., 1998; Stajnko et al., 2009). Therefore, urine puddles are an important source of ammonia emission caused by urea degradation by the enzyme urease (Ivanova-Peneva et al., 2008). The effect of urine puddles on ammonia emission on different floor types (slatted and solid) has been previously observed. The main source of ammonia emission represents urine pools on solid concrete floors (Aarnink et al., 1997; Groenestein et al., 2007). On slatted floors, urine drains into the manure pit as well as entering into the pores of the slats (Groenestein et al., 2007). Therefore, ammonia emissions from slatted floors are not negligible (Aarnink, et al., 1996). In the present study, ammonia emission was significantly influenced by the rearing system ($P \leq 0.001$) (Fig. 5). From the present result, it is clear that available outside space, according to organic legislation, affected pig excretory behaviour, which caused lower ammonia emission from inside the pig unit. Nevertheless, in both rearing systems, ammonia emission rates were lower (max. = 20 ppm) than prescribed by CE.

Ammonia emissions have been related to the age of pigs (Fig. 6). In both periods, ammonia emission rate increased as a linear function within the age of pigs in both housing systems. These results are in agreement with a previous study that analysed ammonia emission in conventional rearing systems (Aarnink et al., 1995). In the first few days of the experiment, ammonia emission rates increased rapidly, which was probably related to the pigs' adaptation to a new environment.

The adaptation period ended on the 4th or 5th day after transferring pigs into the new facilities.

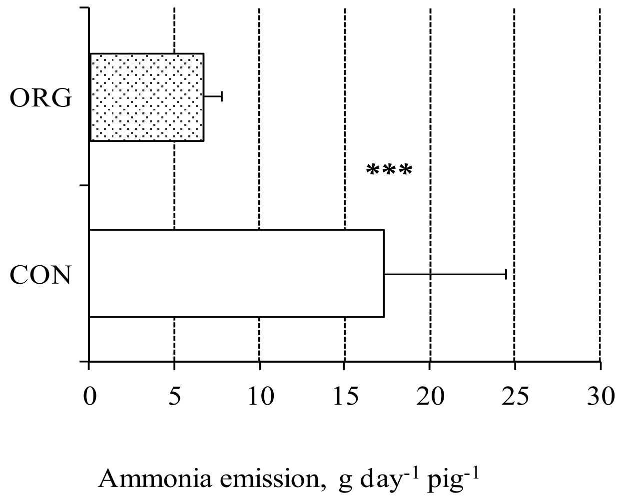


Fig. 5 Ammonia emission in conventional and organic rearing systems

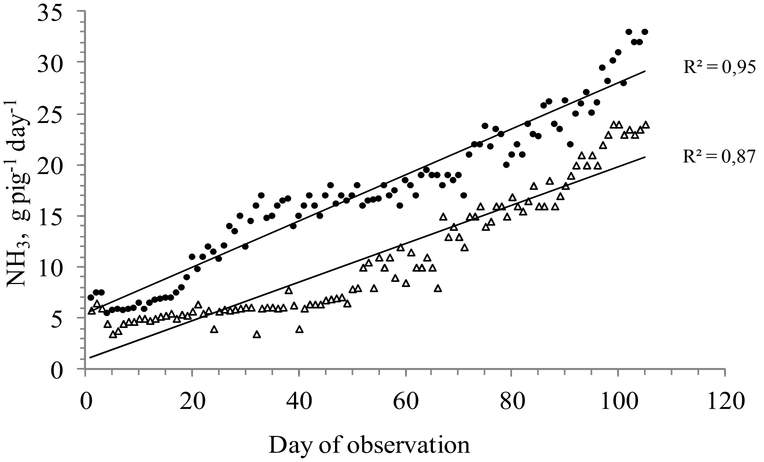


Fig. 6 Linear relationship between ammonia emission and the age of pigs: (●) conventional group, (▵) organic group

CONCLUSIONS

The ECHO system was designed for monitoring microclimatic conditions and ammonia concentration. With this device we were able to control ambient environmental characteristics such as temperature, air velocity, relative humidity and light intensity. We were also able to monitor ammonia concentration. The amount of ammonia emission was lower in organic pig facilities than in conventional facilities. This probably occurred because organic pigs excreted some nitrogen outside. In the future, the ECHO monitoring system could be used as a cheap microclimatic monitoring device for smaller growing pig facilities. In addition, this monitoring device could be upgraded to alert producers when conditions are not in an acceptable range.

ACKNOWLEDGEMENT

This research was financial support by Slovenian Research Agency (project J4-9532). The funding is gratefully acknowledged.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 637.115
Prethodno priopćenje
Preliminary communication

EFFECT OF THE LINER TENSION OVER SOME CHARACTERISTICS OF THE PROCESS OF MECHANICAL MILKING

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SUMMARY

The aim of the paper is to investigate the teatcup of a mechanical milking machine for two different mounting tensions of the liner. The teatcup is the WestfaliaSurge Classic, part no. 7021-2725-350, for cow teats with the diameter between 20 and 27 mm and a mouthpiece diameter of 23 mm; the wall thickness of the liner is 2 mm. When mounted into the shell, the teatcup liner is elongated by 5.4%. The use of a 2 mm thick washer placed at the top of the shell allowed the increase of the liner stretch to 6.9%.

A high milk line milking machine was used, operated at a vacuum level of 47 kPa (54.32 kPa absolute pressure). The system was equipped with an electronic STIMO IQ pulsator, at a fixed pulsation rate of 60 cycles/min; two pulsation ratios were tested: 60/40 and 70/30 %.

An artificial teat, according to the specifications of the ASAE EP445.1 standard, was mounted into the teatcup. The artificial teat was equipped with an A201 FlexiForce (Tekscan) force transducer in order to measure the contact pressure between the liner and the teatcup.

During each test the following parameters were evaluated:

- the real pulsation ratio and rate;

- the duration of the cycle phases;

- the maximum contact pressure between the liner and the artificial teat;

- the critical collapsing pressure difference.

*The experimental results showed that liner tension had no significant effect over the duration of the a+b and c+d phases of the pulsation cycle, while the **a** and **d** phases were affected by the increased liner tension. The liner-teat contact pressure increased when the liner elongation increased*

***Key words**: milking cycle, liner tension, contact pressure.*

INTRODUCTION

Mechanical milking is achieved using the pulsation principle, defined by the ISO 3918: 2007 standard [16] as the cyclic opening and closing of the teatcup liner, which is applied over the teat. Collapse of the teatcup liner beneath the teat is achieved when air at atmospheric pressure is admitted into the pulsation (lateral) chamber of the teatcup; when vacuum is applied to the pulsation chamber, the liner opens, allowing the extraction of milk. Figure 1 presents a typical pulsation cycle, as defined by the ISO 5707: 2007 standard [17]; ***a*** is the increasing vacuum phase, ***b*** is the maximum vacuum phase, ***c*** is the decreasing vacuum phase and ***d*** is the minimum vacuum phase. Theoretically, milk extraction occurs during the ***b*** phase; in practice, some milk is also extracted during the ***a*** and ***c*** phases.

The pulsation ratio is defined as the ratio between the duration of the ***a*** + ***b*** phases and the duration of the entire cycle.

All the researchers agree that the pulsation characteristics affect the milk yield and the health of the animals. According to Bade, Reinemann, Zucali, Ruegg and Thompson [2], the pulsation rate and ratio, the vacuum level and the compressive load applied to the teat when the liner collapses are the factors affecting the peak milk flow rate.

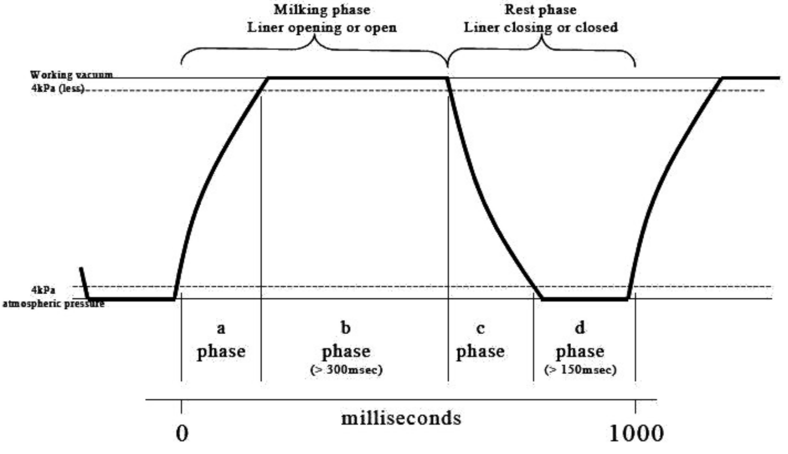

Fig. 1 Definition of the phases of mechanical milking [17]

Adley and Butler [1] stated that inadequate liner collapse could lead to high infection levels, while Mein and Reinemann [10] showed that liner compression during ***d*** phase affected the milk flow rate and that increased liner compression led to the development of teat-end hyperkeratosis.

In a paper presented at the NMC 47th Annual Meeting by Kochman et al. [6] the importance of the ***c*** phase was emphasized; the authors stated that, for a shorter ***c*** phase, the increased closing speed of the liner could cause physical discomfort to the cow, with negative results over the milking performance. In another paper [7] it was also concluded that shorter ***c*** phases led to higher contact pressures between the liner and the teat.

Billon and Gaudin [3] showed that the milking time and milk flow rates were affected by the duration of the ***a*** and ***c*** phases; shorter phases led to longer milking times and lower flow rates.

The problems referring to the effects of the liner tension over the working parameters of the milking machine, in general, and over the liner-teat contact pressure, in particular, were studied by several authors. Thus, Boast et al. [4] stated that the liner-teat contact pressure is governed by the tension in the liner, a decreased liner tension resulting in the decrease of the rubber-teat contact pressure; liner stretch is also causing the reduction of the liner bore. In the meantime, an increased liner tension is expected to lead to a faster opening liner.

Mein et al. [9] showed that a decreased liner tension (due to ageing) led to the reduction of peak and average milk flow.

Following a series of experiments in which high and low tension liners were used, Mein et al. [8] concluded that liner tension has a major effect on pressure difference acting across the oposing liner walls at which milk flow from the teat stopped (higher tension resulted in cessation of flow at a lower pressure difference). They also concluded that incresing the liner tension resulted in higher compressive loads over the teat.

Reinemann et al. [12] also concluded that an increased liner tension led to the increase of the compressive load applied to the teat, while Muthukumarappan et al. [11] developed a mathematical equation in order to describe the effective compressive load as a function of liner tension.

It should be mentioned that all these results concerning the effects of liner tension were obtained for different types of liners, some being more tensioned than the others, due to their dimensions.

The aim of the research described in this paper was to investigate the effect of liner tension when the same liner is used. Different tensions were achieved by placing a 2 mm thick washer at the top of the shell, which resulted in a liner stretch of 6.9%; when no washer was used, the liner mounted into the shell was elongated by 5.4%.

MATERIALS AND METHODS

A high line milking machine was used during the tests, operated at a 47 kPa vacuum level.

The machine was equipped with WestfaliaSurge Classic type teatcups (part no. 7021-2725-350), for cow teats with the diameter between 20 and 27 mm and a mouthpiece diameter of 23 mm; the wall thickness of the liner was 2 mm.

In order to record the short pulse tube vacuum a pressure recording system was developed, using absolute pressure transducers type SPD015AAsil (SMARTEC [18]), with analogical output and the absolute pressure range between 15 and 102 kPa and a response time of 1 ms.

In order to evaluate the liner-teat contact pressure an artificial teat was used, manufactured according to the specifications of the ASAE EP445.1 standard [15] (Figure 2); the teat was equipped with an A201 FlexiForce (Tekscan) force transducer, with a diameter of the sensing area of 9.53 mm.

The sensors were connected to a data acquision board type USB6009 (National Instruments), with a sample rate of 48 ksamples/s and 4 differential analog input channels; a virtual instrument, designed with the LabView 7.1 software package, allowed both the visualization and the recording of the pressure signals.

Both the pressure sensors and the force sensor were calibrated before the beginning of the tests and the following relationships between the applied pressure and the output voltage were established:

- for the absolute pressure sensors:

$$p_a = 106.775 + 18.182 \cdot u \quad [kPa],$$

- for the liner-teat force transducer:

$$p_c = 141.92 \cdot u \quad [kPa],$$

where p_c is the contact pressure between the liner and the artificial teat and u is the level of the signal [V] at the output terminals of the absolute pressure sensors and respectively at the output terminal of the signal conditioning circuit, for the force sensor.

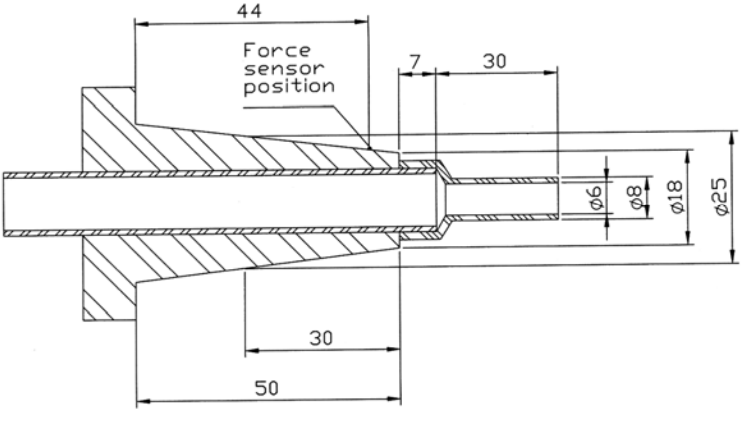

Fig. 2 The artificial teat

The milking machine was equipped with a STIMO IQ electronic pulsator, with a pulsation rate of 60 cycles/min; the pulsator allowed the achievement of two pulsation ratios: 60/40 and 70/30.

Using the notations from Figure 3, the initial liner stretch was calculated with the formulae:

$$LS = \frac{L_2 - L_1}{L_1} \cdot 100 \quad [\%]$$

where L_2 is the length of the teatcup shell and L_1 is the length of the unstretched liner. Taking into account the dimensions of the liner, the initial liner stretch was 5.4%.

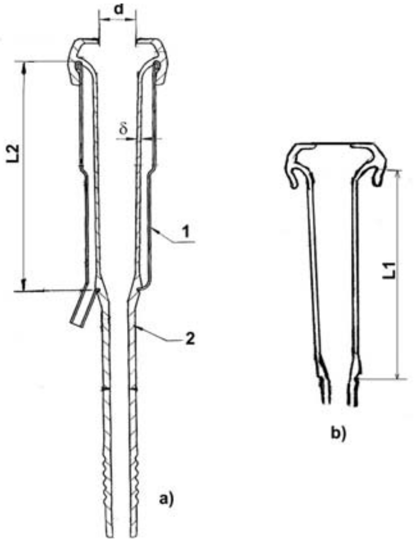

Fig. 3 Teatcup construction and liner dimensions; a) assembled teatcup: 1-shell; 2-liner; d-liner mouthpiece diameter; δ-liner thickness; b) unmounted liner Placing a 2 mm thick washer at the top of the shell resulted in a liner stretch of 6.9%

For each test the following parameters were evaluated:

- the pulsation ratio and rate;
- the duration of the cycle phases;
- the time the teatcup liner is completely open;
- the maximum contact pressure between the liner and the artificial teat;
- the critical collapsing pressure difference.

The pulsation cycle ratio *P* and rate *f* were calculated with the relations:

$$P = \frac{t_a + t_b}{T} \cdot 100 \quad [\%], \quad f = \frac{60}{T} \quad [cycles / min],$$

where $T = t_a + t_b + t_c + t_d$ is the cycle period [s], and t_a, t_b, t_c and t_d are the durations of the respective phases [s].

The time the teatcup was completely open, τ_o (Figure 4), was evaluated with the help of the force sensor mounted on the artificial teat, taking the time when there was no force applied to the teat.

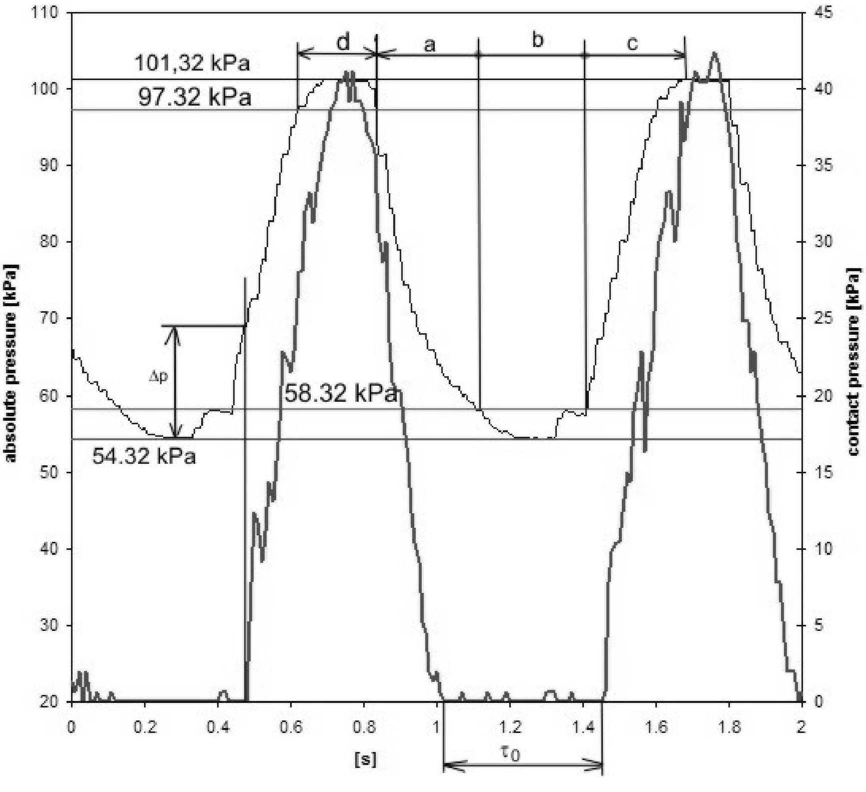

Fig. 4 Intermittent vacuum and contact pressure chart

When the liner was supplementary stretched due to the 2 mm washer, the contact pressure did not reach a zero value, because of the reduction of the liner bore; therefore, the liner was considered completely open as long as the contact pressure did not exceed 10% of the maximum contact pressure (fig. 5).

The maximum contact pressure between the teatcup liner and the artificial teat was measured during the *d* phase of the pulsation cycle.

The critical collapsing pressure difference Δp was defined as the point at which the liner begins to buckle because of the pressure difference across the walls, applying pressure over the teat (during the ***c*** phase of the pulsation cycle) and was evaluated with reference to the absolute pressure inside the teatcup, as shown in Figure 4.

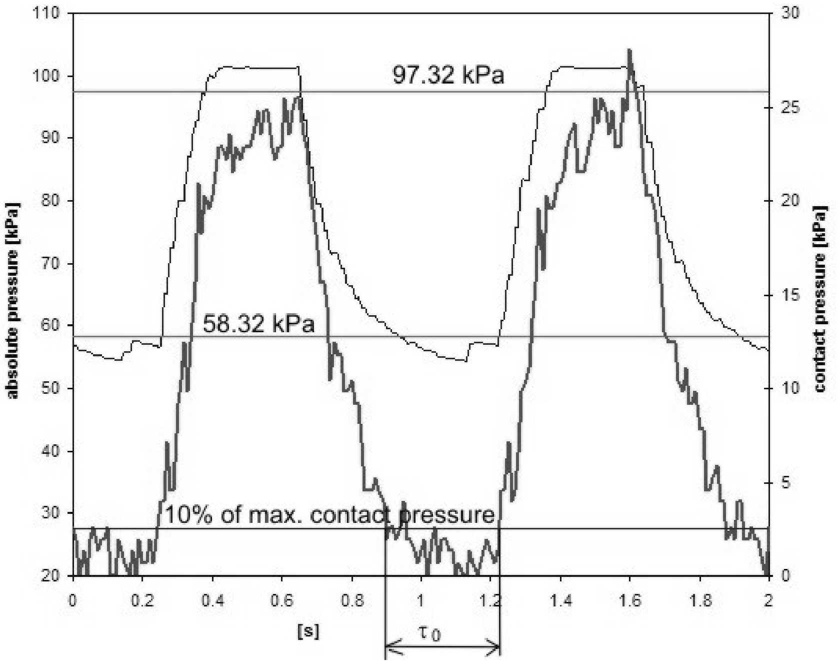

Fig. 5 Time the teatcup is completely open, 6.9% liner stretch

RESULTS AND DISCUSSION

Table 1 summarizes the results of the tests. An analysis of the results obtained for the initial stretch condition (witness, 5.4%) and the liner's supplementary stretch condition (6.9%) proved that there were significant differences between the recorded values ($p<0.05$) for most of the investigated features.

From Table 1 it is obvious that liner tension had no influence over the pulsation frequency, as there are only minor differences between the recorded values. The same is true for the pulsation ratio.

Significant differences were recorded for the duration of *a* phase of the pulsation cycle, for the 70/30 pulsation ratio, when the increased liner tension resulted in a decreased duration of *a* phase. This was due to the fact that the lower mounting tension resulted in a longer time required by the rubber liner in order to expand to its initial shape, or, in other words, in a longer *a* phase.

As long as the duration of the *b* phase of the pulsation cycle is concerned, it was concluded that it increased when the liner tension was increased and there was a significant difference for the 70/30 pulsation ratio.

The overall length of the $a+b$ phase was affected by the pulsation ratio (which was normal, higher ratios leading to longer $a+b$ phases), but not by the liner tension; as a result, a longer *a* phase led to a shorter *b* phase in order to preserve a constant $a+b$ value.

Table 1 Results of the tests

Item	5.4% stretch (witness)		6.9% stretch	
	60/40	70/30	60/40	70/30
a phase [s]	0.283	0.300	0.283	0.277
b phase [s]	0.293	0.383	0.297	0.407
weight of b [%]	**29.8**	38.8	**29.6**	41.1
a+b [s]	0.576	0.683	0.580	0.684
c phase [s]	0.130	0.130	0.207	0.200
d phase [s]	0.277	0.173	0.203	**0.107**
c+d [s]	0.407	0.303	0.410	0.307
pulsation ratio [%]	58.66	69.3	58.8	69.03
pulsation rate [c/min]	61.0	60.8	59.8	60.6
cycle duration [s]	0.984	0.987	1.003	0.990
time compl. open [s]	0.32	0.37	0.437	0.490
critical colap. press. [kPa]	24.35	23.63	25.56	26.20
max. contact press. [kPa]	25.6	29.5	32.5	36.2

The same thing happened with the length of the *c+d* phase: it decreased when the pulsation ratio increased (which was again normal, higher pulsation ratios leading to shorter *c+d* phases), but was not significantly affected by the liner stretch.

The duration of the ***c*** phase was not affected by pulsation ratio, as also shown in another paper [13], but increased when the liner tension increased; this happened because a more tensioned liner takes a longer time in order to deform under the effect of the pressure difference. As the sum of the ***c*** and *d* phases is constant, an increased liner tension led to a shorter *d* phase.

The ISO 5707 standard [17] requires phase *d* to last at least 0.15 s (at 60 cycles/min pulsation rate) in order to overcome the congestion induced by the milking vacuum [9]; the experimental results show that this condition was not achieved for the tensioned liner and the 70/30 pulsation ratio.

The same standard states that the ***b*** phase should not be less than 30% of a pulsation cycle; this requirement was not fulfilled for the 60/40 pulsation ratio. However, even at the abovementioned pulsation ratio (60/40), this requirement was achieved when the time while the teatcup is completely open was taken into account; in this case, the liner was completely open for 32.5% of the cycle duration at 5.4% stretch and for 43.6% of the cycle duration at 6.9% stretch.

The pulsation ratio had no significant effect over the critical collapsing pressure difference; in the meantime, an increased liner tension led to the increase of the collapsing pressure difference (aprox. 24 kPa for the 5.4% liner elongation and aprox. 26 kPa for the 6.9% liner stretch).

The liner-teat contact pressure was affected by both the pulsation ratio and liner stretch. Thus, the contact pressure increased with the increase of the pulsation ratio, probably due to the longer time available for the liner-teat contact. The contact pressure also increased when the liner elongation increased, which is in accordance with the results presented by other authors [12, 14].

CONCLUSIONS

- The effect of the liner tension over some characteristics of the machine milking process was investigated.
- Unlike in other researches, in this research the same liner was elongated diferently, by the means of a washer placed on the top of the teatcup shell.
- While liner tension had no significant effect over the duration of the a+b and c+d phases of the pulsation cycle, an increased liner tension resulted in an decreased duration of the ***a*** phase and a shorter ***d*** phase.
- The duration of the ***c*** phase was not affected by pulsation ratio, but increased when the liner tension increased.
- The results showed that a better evaluation of the time the liner is completely open was given by the presure sensor mounted on the artificial teat compared to the standard definition of the **b** phase of the pulsation cycle.
- An increased liner tension led to the increase of the collapsing pressure difference.
- The liner-teat contact pressure increased when the liner elongation increased.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.798.1:631.564
Originalni znanstveni rad
Original scientific paper

THE INFLUENCE OF PLASTIFIANTS' CONTENT ON RHEOLOGY, MICROSTRUCTURE AND EXPANSION INDEX OF CORN STARCH - BASED PACKING PEANUTS

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SUMMARY

Making biodegradable plastics is a concern of recent years, research in this field from universities, research institutes and enterprises are continuously developing. Biodegradable packing peanuts used as loose fill shock absorbent packaging are also part of the large class of biodegradable plastics and it is necessary for them to ensure, besides biodegradability, a number of technical requirements deriving from their utilization purposes: protection of breakable products during handling and transport. Packaging properties depends on both the type and proportion of materials that are part of the formula and the technology used in its manufacture, process characterized by certain technological parameters.

Thermoplastic extrusion has been used to produce starch-based packing peanuts, in a similar way to the production of extruded expanded snack foods. Native starches are non-plastic due to the intra- and intermolecular hydrogen bonds between the hydroxyl groups in starch molecules, which represent their crystallinity. Thermo-mechanical processing is used to disrupt and transform the semi-crystalline structure of starch granules to form a homogeneous and amorphous material. This transformation is usually accomplished using small amounts of molecular substances commonly known as gelatinization agents or plasticizers.

This paper presents some results obtained during researches conducted in order to obtain biodegradable corn starch-based peanuts by thermoplastic *extrusion, when using in different reports between starch and plasticizers in the formula. Changing the starch - glycerol – water proportion in the formula leads to modification of viscosity value of the mixture and changing structure and expansion index of the finished product.*

***Key words**: biodegradable plastics, shock absorbent packaging, thermoplastic extrusion*

INTRODUCTION

Developing of a sustainable society requires achieving compatibility at a higher level, between the economic, social and environmental systems, which are interrelated, so much to ensure the present needs without compromising the posibility of future generations to meet their own needs, fact that can be achieved by introducing technical progress simultaneously in those three systems.

An area with great impact on sustainable development is that of synthetic plastics, which have known in recent decades a large spread in all areas of life, especially in the field

of packaging, catering, agriculture, construction and automotive.

The current global plastics production level is about 250 million tons, 80 million tons for packaging, and shows a strong and continued global growth (Sain, M.M., 2007). This development is explained by the fact that synthetic plastics are relative inexpensive material, lightweight, durable and resistant.

However, these synthetic polymers are typically made from petroleum or natural gas and are non biodegradable due to their high molecular weight and hydrophobic characters. The petroleum resources are limited and the blooming use of polymers has caused serious environmental problems. Millions of tons of plastics end up in landfills, in the oceans and shores for hundreds of years.

During the last two decades a considerable amount of investment and R&D has been conducted worldwide to identify alternative raw materials that can be used to ensure the environmentally-friendly nature of plastic materials. The development of these materials involves the implementation of appropriate technologies adapted to the quality of local raw materials to achive in this field, too, of some quality organic products as requested by internal and external market.

Starch, as a key component of these renewable raw materials, is becoming an increasingly important input to activities outside the food industry due to the variety of ways in which it can be modified to find applications such as destructured starch. The destructuring agent is usually water. Gelatinization is the disruption of the granule organization. The starch swells forming a viscous paste with destruction of most of inter-macromolecule hydrogen links. Gelatinization is particularly important because it is closely related to the other changes, and it is an irreversible process that includes granular swelling, native crystalline melting, loss of birefringence and starch solubilization. Under shearless conditions (the combination of water and heat) full gelatinization of starch requires more that 63% water content (Wang SS., 1991), while gelatinization under shear conditions requires much less water as shear stress enhances processing. The combination of thermal and mechanical inputs can be obtained by extrusion, a common plastic processing technique. Water acts as a plasticizer but it is a volatile plasticizer. By decreasing the moisture content (<20 wt%), the melting temperature tends to be close to the degradation temperature(Shogren R. L., 1992). To overcome this last issue, is added a non-volatile (at the process temperature) plasticizer to decrease melting temperature Tm, such as glycerol or other polyols (Poutanen K., Forssell P., 1996).

This paper presents some results obtained during researches conducted in order to obtain a biodegradable starch-based loose-fill by thermoplastic extrusion, when using in different reports between starch, water and glycerol in the formula.

METHODS

The normal corn starch used in this study was obtained from SC Amylon SA Sibiu, Romania. The initial water content of starch on dry wet was 12%. The other characteristics of this starch, supplied by the manufacturer are shown in Table 1.

Structure of utilized starch granules was determined (M. Tomoaia-Cotisel, *et al.* 2010).

Table 1 The physicochemical characteristics of corn starch

Ash	Protein	Density	Viscozity
max. 0,1%	max.0,5	0.561 g/cm^3	700 UB (10 min la 95 ^{0}C)

The glycerol used in formula was purchased from SC Nordic Invest SRL Cluj Napoca The glycerol has had a concentration of 99.5% and a density of 1.262 g/cm^3.

The water used was from the water supply system.

The Table 2 indicate the ratio of the two components in the formula, based on which have been established the starch and plasticizer flow rate.

Table 2 The ratio of components in the formula

Formula abbreviation	Water [% wet basis]	Glycerol [% wet basis]
ATN 411	16.66	16.66
ATN 412	14.29	28.57

The technical equipment used (Fig.1), has as main components: the dosing pump (A), the extruder (B) and the feeder (C).

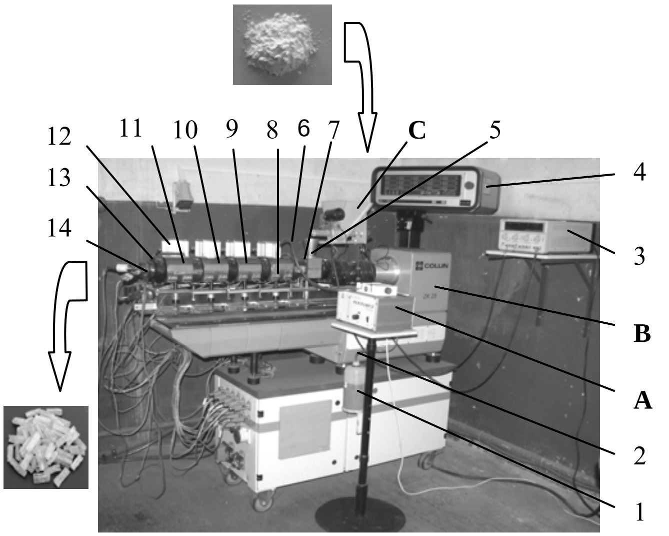


Fig. 1 Extruding installation – general view
A – Peristaltic pump; B - Extruder; C – Feeder
1-Plasticizer tank; 2–Plasticizers feeding pipeline; 3- Power source; 4 – Control panel; 5- Supply hopper for starch; 6-Plasticizer pipe connection; 7-11 Area 01-05; 12-Cooling fan; 13-Area 06-Die; 14-Heater.

The dosing pump used to feed with plasticizers was a peristaltic pump PERIPUMP ‚D' 5187 type, of low capacity and high dosing precision, with a power flow between 1 and 42 ml/min.

The equipment used in experiments was a Collin ZK 25 extruder with two co-rotating screw, with

The feeder used in experiments was a volumetric feeder with one screw.

A laboratory twin-screw extruder with co-rotating intermeshing, self-wiping screws (Model ZK 25, Collin) was use to conduct the extrusions. The extruder has a maximum productivity of 15 kg / h, screw diameter D = 25 mm, screw length L = 30 D, screw speed: max. 400 rpm and six independent heating and cooling areas.

The first area of the extruder, which is the supply area, is not heated, but can be cooled with water. The two to five areas are provided with electric heaters and cooling fans. Each of these five areas is equipped with one temperature sensor that measures temperatures and control starting or stopping of the heaters or fans to maintain temperatures set in each area. The six area of the extruder is the die area - it has its own heater, and no cooling. Its temperature is measured and maintained at the value initially established by the temperature sensor. Also in the die area there are another two sensors that are in direct contact with the material that is processed and measuring its temperature and pressure. These two parameters are very important, for them relying largely the quality and cross size of the extruded product.

Temperature values in these six areas of the extruder are initially set, achieved and maintained during extrusion plant operation with a program whose interface is the control panel of the extruder.

The starch was feed into the extruder hopper with a single screw volumetric feeder. The feeder can achieves starch flow rates ranging from 0.481 kg/h to 5.220 kg/h.

The dosing pump used to feed the plasticizers from the plasticizers tank was a low capacity and high dosing precision peristaltic pump (Model PERIPUMP D’5187, MTA KUTESZ, Hungary), with max. 42 ml/min flow rate. In order to use a single dosing pump both plasticizers (glycerol and water) being miscible, were mixed in the proportion of the formula and placed in the plasticizers tank.

Preliminary study indicated that the premixing starch powder and plasticizers tended to cause bridging in the feeding hopper. Therefore the plasticizers were added into the working area through a pipe connection located at 170 mm from axis of the supply hopper (Fig. 1)

The screw speed was set at 220 rpm and the barrel temperatures were maintained during the experiment at 30, 50, 100, 130, 150 and 150^{0}C, respectively, from the feeding port to the die section.

For the used formulas, the glass transition temperature, determined by DSC analysis, was 73 ºC to ATN411 mixture and 71 ºC to ATN412 mixture.

A circular die plate with one hole was use. The diameter of the hole in the die is 3 mm.

The extruding product was collected and cooled to room temperature. At each experiment samples were taken after the extruder had reached steady state.

RESULTS AND DISCUSSION

The determined parameter for flours and starches of different provenience and which gives clues about their quality in terms of resistance to a force applied at a given temperature is the "falling index".

The device used for this analysis was Falling Time System (Sadkiewicz Instruments, Poland).

The gelatinization of starch suspension took place in a test pipe located in a water bath at 100^{o}C. The estimating of the gelling degree of a suspension is making by measuring and recording, by the device, of the falling time of the agitator in the gel formed. The influence of formula on the falling time of the two samples is shown in Tab.2.

The falling time is both an index of deformability and of baking properties of starch.

Table 3 The falling time and the macroscopic appearance of the sample

Abbreviation	Falling time [sec]	The macroscopic appearance of the sample after gelatinisation
ATN 411	362	The gel has many air bubbles embedded
ATN 412	250	The gel has aspect hollow

In the Table 4 and Table 5 there are presented the results of the experiments for 2 recipes used. The expansion index was calculated as the ratio between the section of the extrudate and the section of the die hole.

Table 4 The aspect of the samples after extrusion

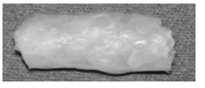
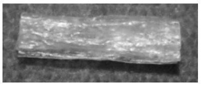
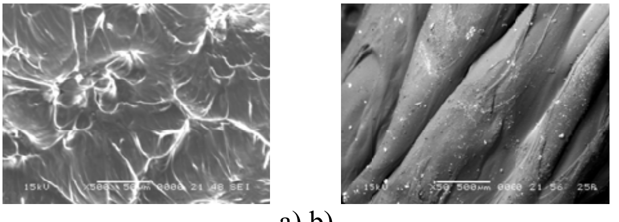
Sample	Symbol	Weight ratio		The aspect of the samples after extrusion
1	ATN 411	starch	4	
		water	1	
		glycerol	1	
2	ATN 412	starch	4	
		water	1	
		glycerol	2	

Table 5 Expansion index

Sample	Symbol	Extrudate`s diameter [mm]	Diameter of the die hole [mm]	Expansion index [%]
1	ATN 411	13	3	21.7
2	ATN 412	7	3	5.4

The microstructures of the finished products obtained by thermoplastic extrusion, for the two formulas used, are shown in Fig.2



a) b)

Fig. 2 SEM images, a – Sample ATN411; b - Sample ATN412

From the SEM images of the finished product made from composite material ATN 411 (Fig.2a) we observe a fibrous structure, while the SEM images of the finished product made from composite material ATN412 (Fig.2b) we observe a deformed rods structure, which are in contact (compact packed).

These differences are explained by different temperatures at which the glass transition take place, deformability and different baking properties and the different macroscopic appearance of the samples after gelatinisation.

CONCLUSIONS

Both plasticizers, glycerol and water, influence rheology, microstructure and expansion index of corn starch - based packing peanuts. Increasing the amount of glycerol in the mixture leads to decrease of falling time. The sample with higher glycerol/water ratio will have slower baking properties and a slower viscosity, having a slower falling time The finished product made from composite material with higher glycerol-water/starch has a deformed rods, compact packed, structure. The expansion index decrease with increasing the glycerin amount in the recipe. The sample ATN412 meet the requirements of a loose fill shock absorbent packaging. Thermoplastic extrusion provides for the required changes in producing of starch based packing peanuts.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

TECHNICAL PROPERTIES OF THE RECYCLED PLASTIC FILMS FROM PROTECTED CULTIVATION

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SUMMARY

In this paper the results of a survey investigating the possibilities to producing a new regenerated film through mechanical recycling, from post-consume agricultural plastic films are analyzed. Four recycled films, made from tunnel and greenhouse covering material, have been extruded and subsequently characterized by mechanical tests and spectro-radiometric analysis. At the same time two new materials made from recycled LDPE and EVA were also tested on their mechanical and spectro-radiometric properties. The results allow the definition of the main engineering properties of these materials, and the possibilities for further investigation in order to have new products as an economic efficient and environmentally friendly alternative.

Key words: *plastic films, mechanical recycling, new film properties*

INTRODUCTION

Due to their properties, plastic materials have a wide range of implementation in industry. Concerning the agriculture, especially horticulture, an extensive and steadily expanding use of plastic films is reported world-wide since the middle of the last century. Some of the reported benefits of using plastic materials in agricultural fields result from increased yields, earlier harvests, less reliance on herbicides and pesticides, frost protection and water conservation (Djevic and Dimitrijevic, 2009). It has also provided a more efficient use of farm land, higher quality of crops and a resultant healthier environment. Furthermore, in arid regions, for example, plastics piping/drainage systems can cut irrigation costs by one to two-thirds while as much as doubling crop yield. In particular, the market of plastics used for these purposes in Europe involves hundreds of thousands of hectares and thousands of tons of plastic films per year.

Apart from their diverse use and contribution to a significant increase in productivity their use causes high quantities of post-consume material that needs to be dealt with in such way that will not cause negative effect on the landscape and agro-ecosystem. In Italy, with the respect to an average annual consumption of more than 350,000 t of agricultural plastic, it is estimated a corresponding flow of post-consume material of about 200,000 t/year. Approximately, 55% of this quantity (Scarascia-Mungozza et al, 2008) comes from protected cultivation (greenhouse claddings, soil mulching, vineyards nets, etc.).

There are many studies that consider the mechanical recycling an appropriate system for recovery of post consumer agricultural plastic film (Scarascia Mugnozza et al, 1997, Gaztelumendi et al, 2002, Scaffaro and Mantia, 2002, La Mantia, 2002, Scarascia-Mugnozza et al, 2006).

The aim of this paper was to presents some research results in the area of plastic materials mechanical recycling. The paper gives the basic mechanical and spectro-radiometric characteristics of the new materials obtained from the low tunnels and greenhouses coverings.

MATERIAL AND METHOD

Materials that were tested and analyzed were used as cladding materials for low tunnels and greenhouses in Almeria and Huelva regions (Spain). Materials were collected and recycled in form of granules by the INSERPLASA S.A. Company. After the granulation the Company extruded four transparent films (G1-G4) different in their mixtures (Tab. 1). The mixtures were also sent to PATI SpA Company that applied different technology to the mixture. They produced densified and granulated mixtures that were extruded and the two new films were made (Tab. 1).

Tab. 1 Properties of the recycled materials

Material	Composition	Thickness [μm]	Type of mixture
G1	LDPE+EVA	40	Regenerated granule of greenhouse film (50%) and low tunnel film (50%)
G2	LDPE+EVA	32	Regenerated granule of greenhouse film (75%) and low tunnel film (25%)
G3	LDPE+EVA	77	Regenerated granule of greenhouse film (25%) and low tunnel film (75%)
G4	LDPE+EVA+HDPE	30	G1 (25%) + G2 (25%) + G3 (25%) + HDPE, from agrochemical packaging, (25%)
Densified	LDPE+EVA	150	Regenerated granule of greenhouse film (25%) and low tunnel film (75%)
Granulated	LDPE+EVA	70	Regenerated granule of greenhouse film (25%) and low tunnel film (75%)

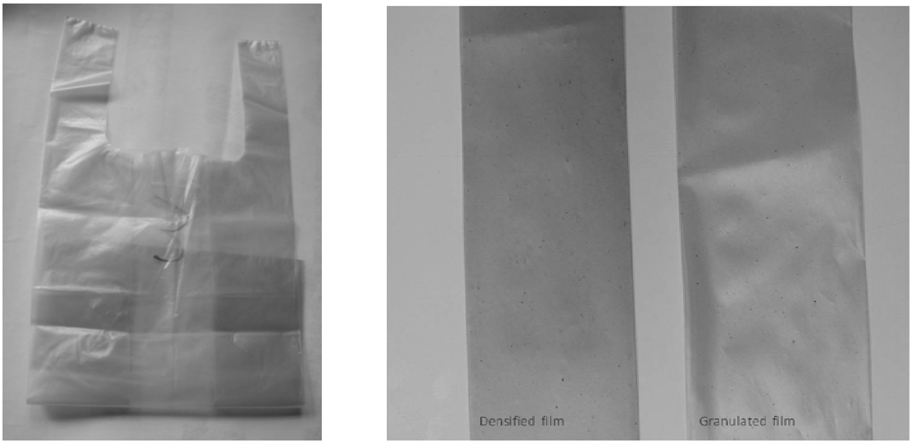

Fig. 1 The form of new regenerated films

All these films were subjected to mechanical test in the Laboratory of Material Testing of the Technical-economic Department of the University of Basilicata, Italy. For each material n.10 specimens were cut. Five specimens were taken along the parallel direction of the extrusion and five specimens in the transverse direction. The tensile tests were conducted, using a computerized universal machine Galdabini PMA 10 (Fig. 2), according to the Italian UNI 8422 Standard (UNI, 1982), at constant deformation velocity of 200 [mm min^{-1}]. Each test concerned 10 specimens, so expressing the results in terms of average value and bilateral confidence interval with 95 % probability (UNI 5309, 1966). The results obtained from tensile tests were reported in terms of maximum resistance (σ_{max}) expressed in [MPa], percentage elongation (ε) and percentage elongation at break (A) expressed in [%].

Fig. 2 G2 tensile test

The spectro-radiometric analysis, aimed to the definition of the optical properties of the six regenerated films, has been realized in the Laboratory of Spectro-radiometric Analysis of the DISAAT Department of the University of Bari - Italy, using the spectro-photometers Perkin-Elmer UV-VIS and FT-IR 1760X.

The transmittance to radiation in the wavelength range from 190 nm to 25000 nm was determined. An integrating sphere was used to evaluate the diffuse fraction of the transmitted radiation in the PAR range.

RESULTS AND DISCUSSION

Mechanical properties of the new materials

The results of the tensile test obtained for the regenerated materials, show that there are differences in terms of maximum resistance (σ_{max}) and percentage elongation at break (A). The values of the maximum resistance varied in the range of 12.38 – 40.45 N mm^{-2} (Tab. 2). The lowest resistance was observed for the material G3 and it was similar in both directions. Material G2 had the highest maximum resistance regardless the tension direction. These results would suggest a better behavior of the material that was a mixture of 75% greenhouse covering and 25% of the tunnel covering.

The results of densified and granulated films, instead, show that they are both characterized by a similar maximum resistance in the longitudal direction while the granulated film has a maximum resistance higher than densified in the transverse direction.

Tab. 2 Results of the tensile tests on the recycled films

Type of the material	Longitudal tension direction		Transverse tension direction	
	A (%)	σ_{max} (N mm^{-2})	A (%)	σ_{max} (N mm^{-2})
G1	252.51±56.44	20.82±3.33	240.98±45.06	20.38±5.26
G2	270.30±22.75	30.97±4.77	350.72±35.67	40.45±4.01
G3	279.77±13.91	12.38±0.62	244.13±89.98	12.69±3.13
G4	196.70±104.90	29.38±5.81	298.67±19.25	30.48±7.47
Densified	171.12±21.9	15.70±1.05	211.28±48.26	15.11±2.19
Granulated	144.75±67.42	16.85±2.83	236.99±23.95	20.59±4.61

The values of the elongation at break of the six films varied significantly in a wide range (144 – 350%) confirming the considerable un-homogeneity of the blends obtained by using recycled agricultural films. Based on the tensile test it can be concluded that the G2 material has a high resistance in both directions and best elasticity when tensioned in transverse direction. The lowest maximum resistance was observed for the material G3 in both directions. Granulated and densified materials had the lowest elongation at break, particularly along the parallel direction.

In any case it is important to consider the difference of the thickness when these recycled films are compared with virgin ones. In principle, the densified material should be compared with a greenhouse film, due to its thickness (150 μm) while the granulated and G3 (respectively 72 and 77 μm) with low/middle tunnel films, and the remaining G1, G2 and G4 (30÷40 μm) with mulching films.

Specifically, the mechanical properties of the granulated and densified films showed a drastic decrease of performance since their resistance to break was very close to a value of 50% of the average values related to a film extruded with virgin raw material. G2 and G4 materials were characterized by a maximum resistance in both direction, higher than that of a virgin LDPE film thickness of 50 μm (about 20 N mm^{-2}).

Spectro-radiometric properties of the new materials

All the regenerated films showed spectro-radiometric characteristics quite similar between them (Tab. 3). Analyzing the behavior of the films in the solar wavelength range, and specifically in the P.A.R., it is possible to note that materials G1, G2, G4 and granulated had a transmittance higher than 80% while G3 and densified film were characterized by a total transmittance less than 80%. Concerning the fact that material G4 was made as a mixture of greenhouse claddings and agrochemical plastic packaging it is interesting that transmittance was higher than 80%.

All materials had a high absorbance to UV radiation which is related to the potential photo-degradation of the polymer by sunlight. This characteristic can be appropriate if the G1, G2 and G4 materials are going to be used as mulching materials but in other case it leads to faster deterioration of the material. The highest transmissivity was observed for G1 material (76.4%) and the lowest for the densified material (40.3%).

The greenhouse effect of the protected cultivation technique used depends on the opacity of the materials to long-wave infrared radiation. In the long IR wavelength range, only the densified film showed a low value ($\tau \approx 0,24$) while all other films were characterized by significantly higher transmittance values than optimal value of a greenhouse covering films ($\tau \approx 0,35\text{-}0,40$) stated by Papadakis et al, (2000). This is the reason why they can't generate a sufficient "greenhouse effect" and act as good greenhouse covering material. A reason for such high IR transmittance could be the low material thickness (lower than 70 μm). The other reason can be that no additives were used in the process of recycling and generating of tested materials.

The final properties of the new recycled material depend on the amount of degraded polymer but mainly on the extent of degradation. When the degradation of the polymer is limited, good properties can be achieved, but if the degradative effects are more pronounced, there is a general worsening of all the properties (Scaffaro & La Mantia, 2002, Briassoulis, 2005). The degradation effects are connected to the applied production technology (plant protection chemicals, fertilizers, type of fertilizers, ways of application etc.), production location (micro climatic conditions, air and water compositions) and conditions of materials storage before recycling. Further chemical analysis of the samples can give some results that can help in improving the materials characteristics and the whole recycling process and management scheme by describing the conditions of collecting, storage and preparation of the materials that are supposed to be recycled.

Tab. 3 Results of the spectral analysis for the new materials

Wave length range	Measured parameter		Material					
			G1	G2	G3	G4	Den.	Gran.
Solar (200-2,500 nm)	Transmission	Total (%)	84.7	84.0	79.1	82.8	77.3	84.9
		Direct (%)	59.4	60.2	54.1	59.6	33.2	45.7
		Diffuse (%)	25.3	23.9	25.0	23.2	44.1	39.3
	Reflection		8.0	8.6	8.0	11.3	7.9	7.6
PAR (400-700 nm)	Transmission	Total (%)	84.1	83.2	76.3	81.5	73.9	82.4
		Direct (%)	51.7	52.1	42.2	50.1	26.1	36.8
		Diffuse (%)	32.4	31.1	34.1	31.4	47.8	45.6
	Reflection		8.4	9.2	8.4	12.7	8.3	7.9
Solar IR (700-2,500 nm)	Transmission	Total (%)	85.6	85.1	81.9	84.3	81.9	88.3
		Direct (%)	66.7	67.8	65.1	68.5	40.1	54.2
		Diffuse (%)	18.9	17.3	16.8	15.8	41.8	34.2
	Reflection		7.6	8.1	7.5	10.1	7.6	7.4
UV (280-380 nm)	Transmission	Total (%)	76.4	74.8	74.7	67.1	40.3	57.2
		Direct (%)	38.4	36.1	38.4	29.3	11.8	21.1
		Diffuse (%)	38.0	38.6	36,3	37.8	28.5	36.1
	Reflection		9.9	10.1	9.9	11.0	7.9	8.6
Long IR (7,500-12,500 nm)	Transmission	Total (%)						
		Direct (%)	63.2	78.4	64.9	73.3	24.1	49.6
		Diffuse (%)						
	Reflection		9.7	5.1	12.3	8.7	4.0	6.3

CONCLUSIONS

The strategic contribution of plastic materials to the development of the agricultural sector is testified by their increasing use, stimulated by a constant research of new polymers and blends by the chemical industry, in protected cultivation, pasteurization of soil, irrigation and drainage, and packaging for harvest, transport, storage and sale of agricultural products.

The solution of the problem of agricultural plastic waste passes through the research of new applications of the recycled material. One of the most interesting ways appears to be the re-utilization of the agricultural wastes in the same sector, through the realization of cheap and effective products able to improve agricultural production.

In this paper six recycled materials were tested to mechanical and spectro-radiometrical properties. Results show that without adding any additives satisfying mechanical properties can be obtained if materials were extruded from mixture that consisted of 75% of greenhouse covering materials and 25% low tunnel coverings. Good mechanical properties were also observed with material extruded in higher thickness when combination of 25% of greenhouse covering and 75% low tunnel covering was used. Spectral analysis revealed that all materials, except G3 and Densified material had visible light transmissivity higher than 80%. G1 and G2 materials showed good properties for being threaten as thermic diffusion film, according to the EN 13206 standard but had the limitation in lower thickness. It can be concluded that with addition of adequate additives these recycled material could find their implementation in horticulture as mulching or covering materials.

Mechanical recycling represents the simplest way of managing plastic waste and, in the same time obtaining new plastic materials that can be re-used in the agricultural sector. By recycling the different mixtures of cladding materials for low tunnels and greenhouses, new materials, having satisfying optical characteristics and mechanical ones in terms of resistance can be made.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

MICROSCOPIC ANALYSIS OF METALLIC MATERIALS CORROSION BY CONTACT WITH MOIST AGRICULTURAL PRODUCTS

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SUMMARY

In contact with moist agricultural products, some metal materials may undergo some changes, especially at the surface, largely due to corrosion. Moist food materials can be an aggressive nature towards metallic materials. Their corrosion resistance and strength is noted in corrosion on the surface, but development in areas with surface imperfections. On these materials, oxide film, more resilient, have different thicknesses, with a passive and unstable character, quite vulnerable to biological attack, and this proved to microscopic investigation and this limits. Microscopic aspects of degradation processes are induced at the interface metallic material – moist biological product. Microscopic analysis of metal samples, investigated with the most advanced equipment, using both optical microscopy and by electron microscopy. He could notice the presence of corrosion by multiple forms of expression, adding some unexpected issues. It has made some forms, quite low, inter-crystalline erosion, especially in softer materials. These metallic materials also were observed punctuate forms of corrosion. The stainless steel samples were observed mainly localized forms of corrosion (type "pitting"). These forms of corrosion can be primed and/or propagated, thus accentuating the surface degradation.

Key words*: metallic material, corrosion, microscopic study, moist agricultural products, degradation, optical microscopy, electron microscopy*

INTRODUCTION

In nature, most agricultural products are colloidal substances which crystallize poorly or not at all. The colloidal structures are systems consisting of a cluster containing the intermediate particle size between molecules and macroscopic particles. The most common parameter used to define the status of the material is moisture. The mechanism of moisture transfer inside and his body is a complex phenomenon that depends on many factors including the structure and material humidity, surface tension and viscosity of water, temperature and relative humidity of the drying agent. [8], [5]

Metallic materials are most support of productive activities in agriculture and food industry. These metallic materials are part of the material universe and are composed of substances whose properties make them useful in carrying machines, devices, products, etc.. After fulfilling their role in the operation, these materials are converted into oxides, sulfides, etc.., or are returned in the process for obtaining new materials, more economical and environmentally friendly process. [6]

In the contact with moist agricultural products the metallic materials are subject to certain adjustment, especially on the surface, largely due to corrosion. The moist agricultural products, some foods may have reached an aggressive character to the metal. For to monitor the behavior of these elements in contact, moist agricultural products and metallic materials, it have been studied the several microscopic aspects of the degradation processes which are induced at the interface metallic materials - moist biological product. Microscopic analysis of metal samples was conducted with the most advanced equipment, using both optical microscopy and electron microscopy. So it can see the presence of corrosion on multiple forms of expression, with possible unexpected phenomena. [1], [3], [8]

THEORETICAL APPROACH

Generally, corrosion is the phenomenon of partial or total destruction of metallic materials after chemical or electrochemical reactions.

Aggressive nature of the solution may be given by the hydrogen ion concentration (pH) which affects the corrosion of metallic materials in two ways: increasing environmental acidity favors, on the one hand, corrosion, and on the other hand changes the degree of solubility of corrosion products and they are deposited on the metal surface, protecting it. Thus, amphoteric metals (Zn, Al, Sn), which are dissolved in acid and alkaline medium, low corrosion rate is neutral, and the soluble metals (Ni, Mg) their stability increases with increasing pH value only in acid medium. The iron is dissolved in medium at pH > 13, suffered an inter-crystalline corrosion, molecular oxygen present in most liquids technology has two actions: on the one hand accelerate corrosion by electrochemical processes conducted at the limit of the two phases, on the other hand increases the resistance corrosion due to formation of protective oxide films. [2]

In the food industry, especially for stainless steel, punctiform corrosion occurs.

The main factors that may affect the corrosion behavior of a material are:

- corrosive environment parameters;
- design parameters;
- characteristics of the material.

The raising of the temperature usually increases food corrosion rate. In chemical plants, environmental attack depends on temperature, concentration, fluid velocity, degree of aeration, pure and applied voltage. [8]

In the case of alloys and in particular of the element chromium is likely to spread in layers of protective oxides producing a metal matrix depletion in this element.

To overcome a certain temperature oxides cracks or peeling and oxidation process is resumed from a matrix depleted in protective element. In this way the kinetics of corrosion is accelerating strongly.

By their good corrosion resistance, stainless steel brings a modern and effective solution of problems posed by spontaneous return of normal metals and alloys in their combined state, stable in nature, usually in the form of oxides. The corrosion, which expresses this trend may evolve by different processes (intercrystalline corrosion, cavernous (cracks), by points (pitting), under power, contact or galvanic) that depend, fundamentally, the electrochemical parameters of the couple metal-environment. [2]

METHODS

Figure 1 Scanning electronic microscope Inspect S. (National Institute for Electrochemical and Condensed Materials of Timişoara)

Conducted experimental research aimed at studying the behavior of five types of metallic materials in contact with several categories of agro-food products:

- Aluminum plate 1050, according to EN 485/573, H24;
- Brass sheet, thickness: 0.4 mm, an alloy Cu-Zn, according to STAS 199/2-86, CuZn37;

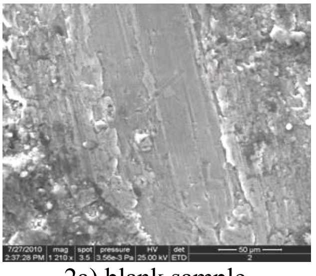
- Cold rolled sheet (black), thin, 0.4mm, EN 10130 + A1, SR EN 10131 / EN 10 131;
- Galvanized sheet according to SR EN 10327/04, steel grades: DX51D + Z150-N-A-C;
- Austenitic stainless steel plate chrome-nickel, with the addition of titanium, 1.4541 / X 6 CrNiTi 18-10 / DIN EN 10088 / DIN 17 440, AISI 321 / BS 321 S 31 / SIS 2337. [9]

Microscopic analysis was performed in one situation: Electron microscopy of metal samples with a microscopic electronic scan INSPECT S, in the specialized laboratory of the National Institute of Electrochemistry and Condensed Matter Timisoara.

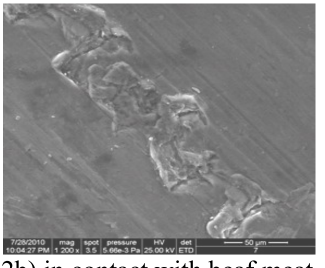
The behavior of metallic materials in contact with agro-food products is performed taking into account the actual conditions of industrial units and the particular laboratory facilities.

RESULTS AND DISCUSSION

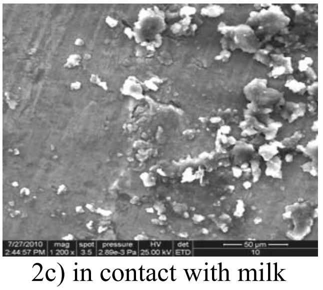
To achieve the objectives of this work, experimental research has focused on the analysis of metallic materials for construction trays used as support for agrimaterial food. Figures 2 – 5 show microstructure of metallic materials that have been in contact with agro-food products.



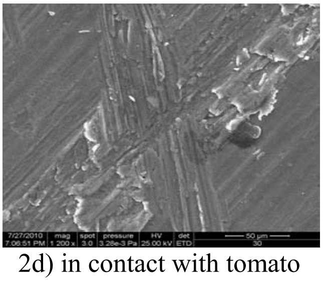
2a) blank sample



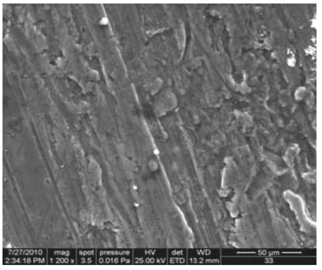
2b) in contact with beaf meat



2c) in contact with milk



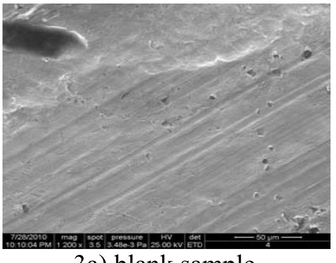
2d) in contact with tomato



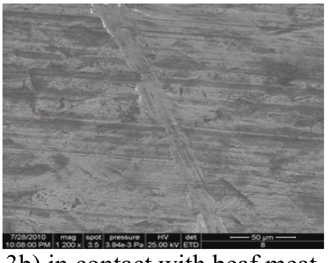
2e) in contact with lemon

Figure 2 (ME 1200x) Microscopic representation of the aluminum plate in contact with agro-foodstuff

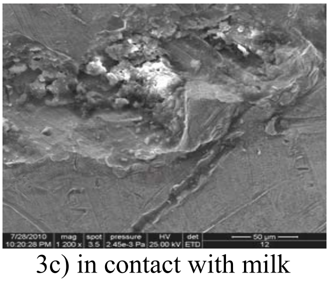
The corrosion seen in the case of aluminum sheet in contact with milk have a local character, it is very strong, penetrating the oxide film with a location in the craters of the fine particles formed by biological characteristics of agro-food contact.



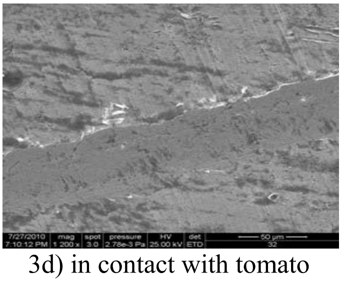
3a) blank sample



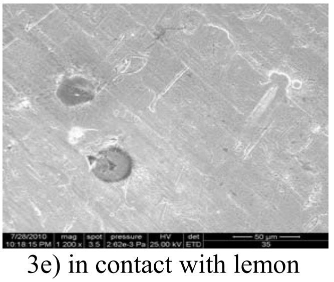
3b) in contact with beaf meat



3c) in contact with milk



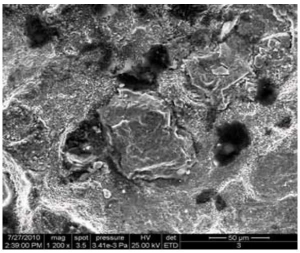
3d) in contact with tomato



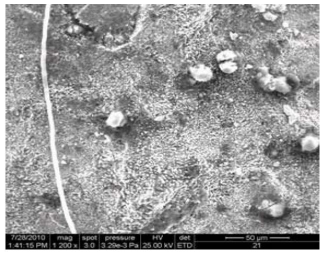
3e) in contact with lemon

Figure 3 ME 1200x Microscopic representation of the brass plate in contact with agro-foodstuff moist

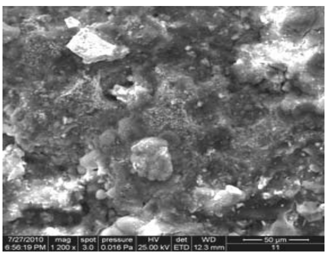
It is found that the brass plate is disadvantageous in terms of corrosion, showing considerable sensitivity to all agro-food products, especially the tomato and lemon, which are distinguished corrosion of "pitting" and increases of previous craters. Also, in many places it is observed the penetrations of oxide film existing at the material with a form of deposit thin films of a biological, powder specific food, especially liquid food, or moist the surface of contact with tray.



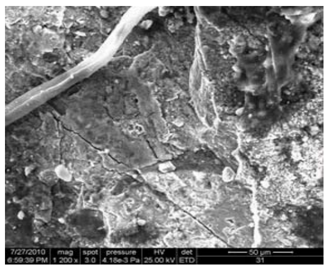
4a) *blank sample*



4b*) in contact with beaf meat*



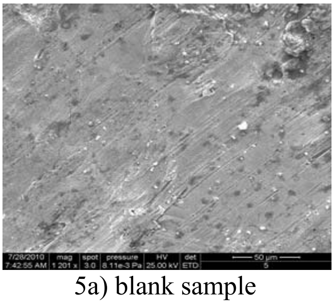
4c) *in contact with milk*



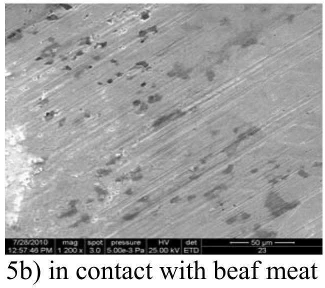
4d) *in contact with tomato*

Figure 4 ME 1200x Microscopic representation of the cold rolled sheet in contact with agro-foodstuff

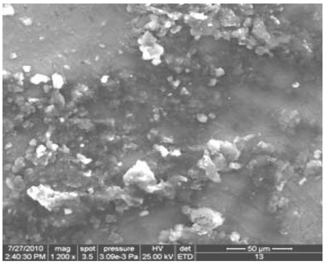
After the microscopic study there is an influence of thermal cycle.



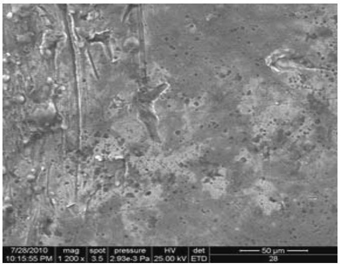
5a) blank sample



5b) in contact with beaf meat



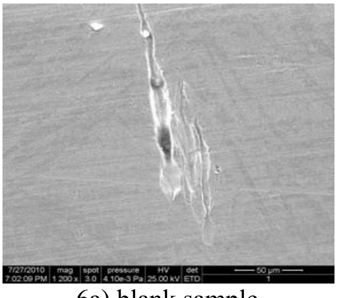
5c) in contact with milk



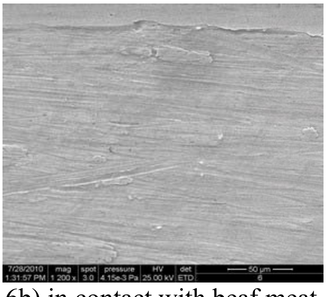
5d) in contact with tomato

Figure 5 ME 1200x Microscopic representation of the galvanized sheet in contact with agro foodstuff moist

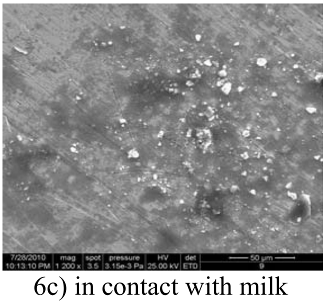
The formations such as metal oxides and form, which still existing on the surface of galvanized sheet, create areas suitable fixing concomitant biological film of sediment from milk powder, creating great difficulty in cleaning the physic-chemical trays. Interfacial processes such as physic-chemical interactions may be the origin of such redox (reduction oxidation). [5]



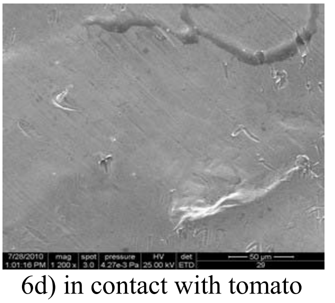
6a) blank sample



6b) in contact with beaf meat



6c) in contact with milk



6d) in contact with tomato

Figure 5 ME 1200x Microscopic representation of the Austenitic stainless steel plate in contact with agro-foodstuff

The corrosion resistance of stainless steel stands lower the intensity of corrosion on the surface, but with the development in areas with surface imperfections. These steels the oxide film is more resistant, with other alloys, this presents a very small thickness, with a passive and unstable character, quite vulnerable to biological attack, and these proved to present microscopic investigation limits.

CONCLUSIONS

After the microscopic analysis applied to the metallic materials mentioned above, during the different processes when that are in contact with some moist agro-food products, the authors found some significant features. Observed forms of corrosion reflect a specific behavior of different types of metallic materials in relation to the aggressive behavior of agro-food moist.

It can note the presence of corrosion by multiple forms, adding some unexpected issues. Were determined certain shapes, quite low, inter-crystalline erosion, especially in softer materials (blackboard, brass, galvanized sheet). These metallic materials also were observed some points as forms of corrosion. At the stainless steel samples, mainly localized forms of corrosion (type "pitting") were observed. If the trays are reuse, these forms of corrosion can be propagated, thus emphasizing the surface degradation.

Also, the appearance of novelty of this research is the presence of two types of film, protective film, comprising basic metal oxides and biological films, characteristic for the each type of agro-food product moist. One is the biological film that can be observed in the areas including surface imperfection, previous craters, scratches, traces of the previous processing.

The situation of the state of corrosion more pronounced (in some materials: black metal, brass, galvanized, aluminum), or less visible (the stainless steel plate), constitutes a threat for reuse trays, especially when the cleaning cannot be achieved with sufficient accuracy. From these results the observation it must to have established the maximum acceptable number of reuses, the occurrence of contamination within the moist agro-food product. The danger resulting from these investigations, using the aluminum plates, is due of the attack the agro-food compositions, in the intimate level of the metallic material.

These research results lead to the need for the manufacturers of agro-food machinery and equipment to establish optimum metallic material that can be in contact with agro-food products moist, so that during contact there are no mutual influences unfavorable to wear by corrosion of metallic materials, and/or some distortions of the quality of agro-food moist.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Expert paper

RESEARCH REGARDING GRAIN DYNAMIC ON THE SIEVE IN THE CLEANING PROCESS

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SUMMARY

Sorting efficiency on plain sieves still represent a problem estimated in most situations on statistical and probability methods. The research carried out and presented in this paper had as main objective real phenomenon dynamics analysis that occur at grain movement on the sieves. Using a high resolution video camera (HiSpec 5) it was carried out shootings for two kinematical conditions characteristic of cleaning equipment from the C-12 grain threshing combine (made in Romania). After grain displacement processing records, the kinematics analysis revealed some aspects that can supplement theoretical assumptions based of grain movement on the sieves such as: besides general advance movement it's also registered a transversal movement resulted from grain collision between them or between grain and segmental plates; the advance movement varies on the sieve segment, registering higher amplitudes on previous segment after they come out uniformly; the grain speed on the sieves is between [-26;20] mm/s and acceleration between [-178;258] mm/s^2.

The research carried out allows new ways in modeling the grain movement on the sieves in order to increase the sorting efficiency.

***Key words**: grain, sieve, track, video camera, recording.*

INTRODUCTION

The literature provides general information regarding the movement of grain on the sieve. Kinematical models developed take into consideration general appearance recognized regarding grain movement on the sieve in the case of single kernel.

The real process is more complex and concerns secondary movements that amounted have a significant role such as:

- grain collision between them with low coefficient of restitution
- grain collision with sieve's sorting plane

- grain collisions with sieve's separating shades
- accidental jumps

All these secondary movements are able to modify the grain kinematic movement on the sieve in terms of position, velocity and acceleration with direct effect on the sorting efficiency.

The investigation of these secondary movements bring into consideration one compose kinematics regime that can be developed only through inverse analysis based on laboratory tests, mathematical models and experimental results. From this point of view, the number of variables taken into consideration in sorting process increase compared with classical mathematical model and analysis complexity is higher.[2]

METHODS

There are two ways offered by the literature that can be applied:

- energetic model - take into consideration kinetic energy consumed by the grain in movement with collision
- kinematics model - take into consideration the variation of position , velocity and acceleration at the movement of grain on the sieve to sort.

In order to realize a grain movement real analysis on the sieves, it was carried out, in laboratory conditions measurements that contains in grain movement video recording with a high resolution video camera followed by the recording analysis in order to establish grain trajectory in their movement on the sieves during cleaning process.

A certain amount of grains was painted in order to make the distinction between the target grain and the rest mass of grain. The tests were carried out at two kinematics regimes: first at 254 rev/min and second at 415 rev/min.

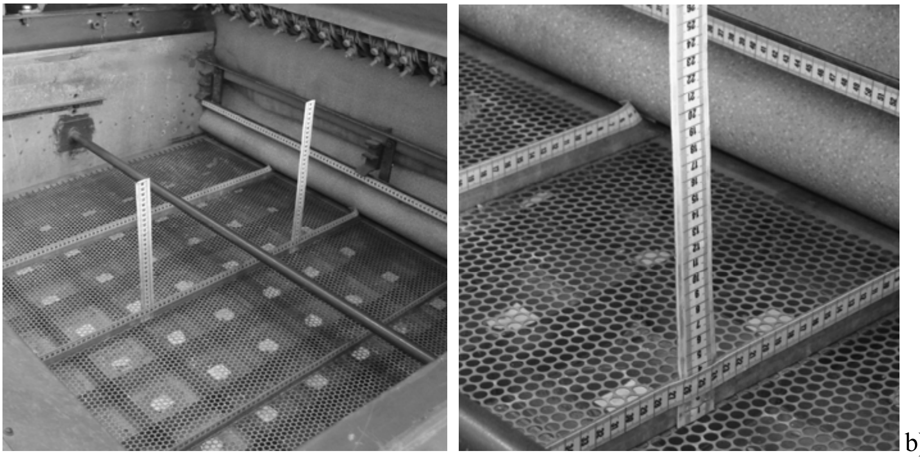
a)  b)

Fig. 1 Experimental stand sieve with mark tapes: a) overview, b) detail

To determinate the exact movements of grain on the sieves, were attached marked tapes in millimeters and centimeters, to determinate movement on height, length and width of the sieve (figure 1).

For recordings it was used Fastec HiSpec 5, a 3 megapixels high resolution high-speed camera. It provides superb quality images with its 1696 x 1710 resolution and it's a perfect fit for a wide variety of high-speed motion applications with the capability to capture up to megapixels images at more than 1400 fps (figure 2).

Fig. 2 HiSpec 5 high speed camera

Camera specifications: [6]

- recording rate: up to 523 fps at full resolution; up to 298,851 fps at reduced resolution
- memory: 4 GB
- recording time: 3.2 seconds at full resolution
- frame format: BMP, TIF, DNG, JPG or AVI file format
- camera/PC interface: 1000/100 Ethernet interface
- camera weight: 0.9 kg, without lens
- operating environment: +5° to +45° C
- power supply: 10 – 30V DC external power supply
- power consumption: 15W maximum.

For the recordings, the camera was positioned in the left side of the stand (figure 3), to allow the registration of grain movement along the length of the sieve and to ensure a good clarity of recordings, the stand was illuminated with additional high power adjustable spotlights.

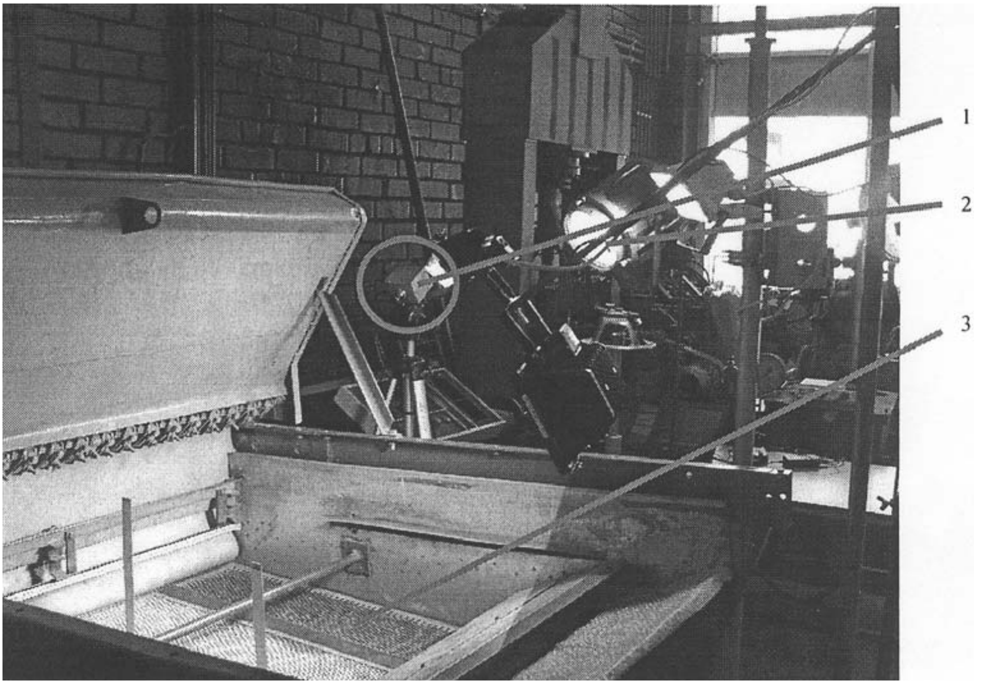


Fig. 3 Experimental stand ready for measurements: 1- high speed video camera, 2-spotlight, 3-sieve

RESULTS AND DISCUSSIONS

The recordings were carried out using HiSpec software and shooting analysis were made with MaxTRAQ software that allowed to mark a grain, track it and draw the graphics of position, velocity and acceleration.

The software displays the images recorded by the camera, image on which will be selected a target grain in order to tracing its trajectory. Under the image is shown the date on which measurements were carried out, data details, the number of frames, shooting resolution and recording duration. Tracking the grain movement on the sieve is accompanied by tracing its coordinate's graphics (figure 4). The software allowed to select the other two kinematics parameters –velocity and acceleration, so the user can choose the kinematics analysis parameter (figure 5). Scrolling pictures are done frame by frame, with the possibility of running back and forth images, increase playback time, setting a start and end time, change the contrast and brightness.

The software bar menu allows to display on image grid lines in order to simplify the method for measuring the grain movement, it is possible image rotation, its negative view, attaching notes to specific points.

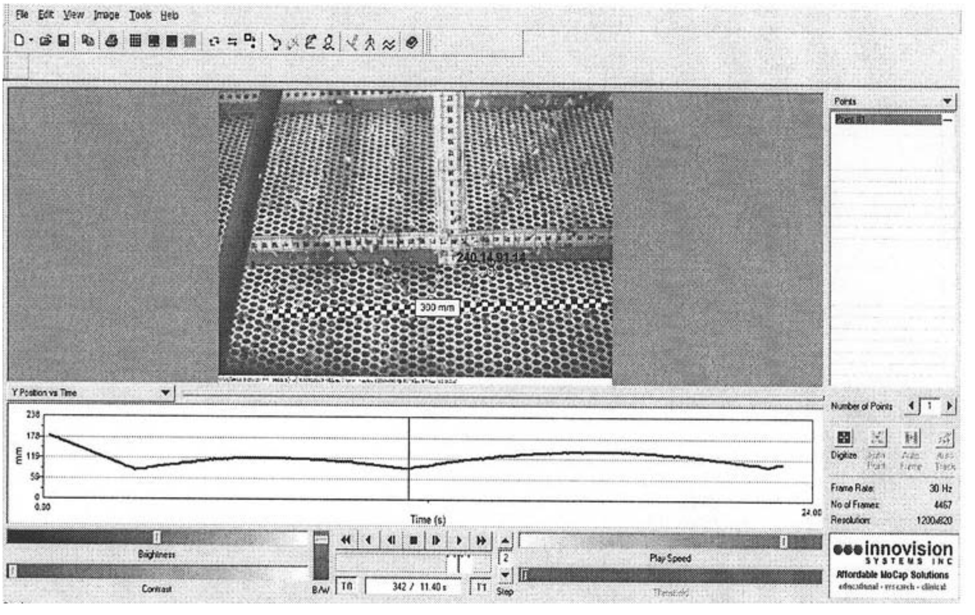


Fig. 4 MaxTRAQ software interface

The graphics obtained by tracking the movement of the grain on the sieve were reported to the mesh length, graphics that are presented in figure 5.

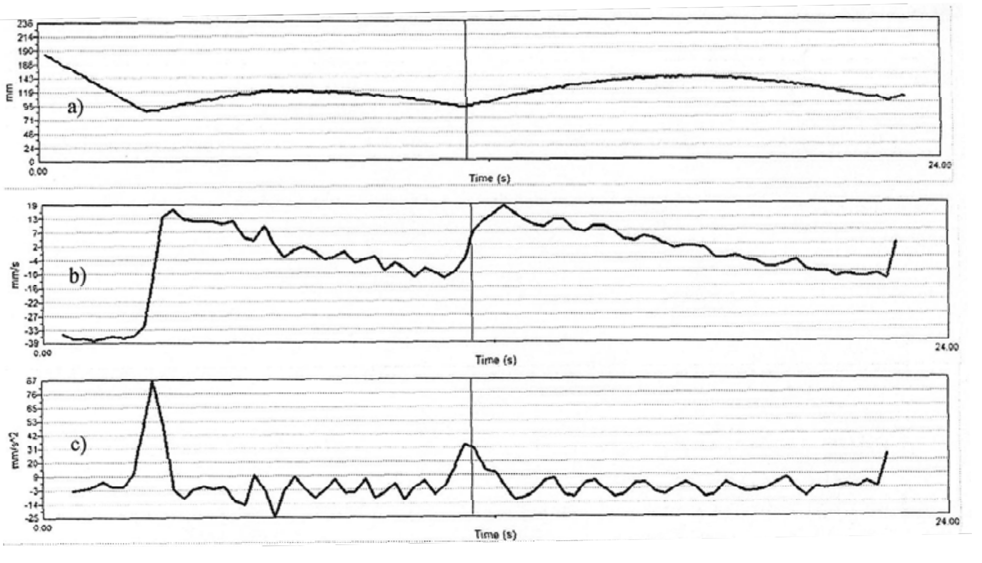


Fig. 5 The graphics obtained in MaxTRAQ software: a-position, b-velocity, c-acceleration

Detailing grain movement on the sieve by using instant values that determines the position on sieve length within a second was made in Origin 6.0 software (figure 6). In this purpose it was extracted capture from the images seen in MaxTRAQ the instantaneous positions of the target grain (paint in black).

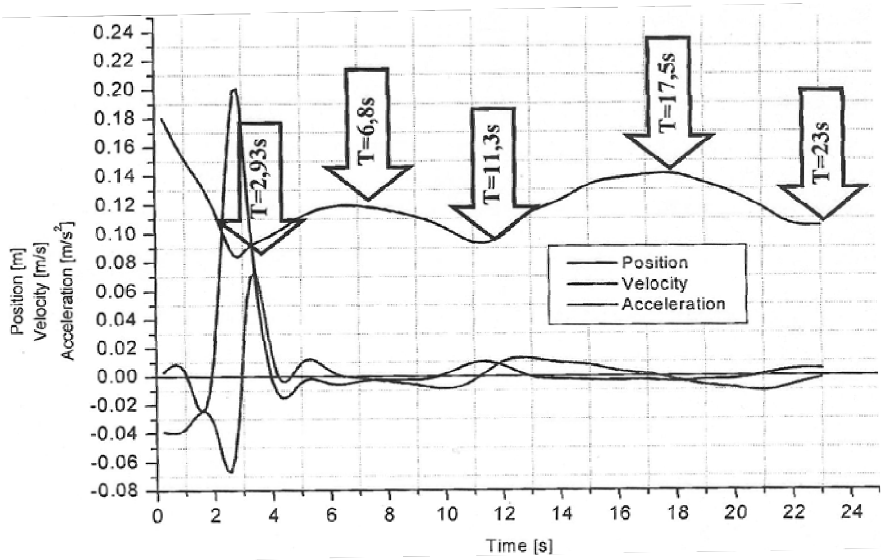


Fig.6 Graphics of position, velocity and acceleration of target grain at the frequency of 415 rev/min – experimental data kinematics evaluation

Velocity an acceleration graphics in Origin 6.0 were obtained by calculating the first and second differential of space. To determinate the grain trajectory sets of measurements were carried out for two kinematical regimes of the stand: the sieves frequency oscillation of 254 rev/min and 415 rev/min. In the first case of 415 rev/min, were obtained graphics of position, velocity and acceleration of target grain.

In table 1 are presented the values of position, velocity and acceleration at every 2 second of measurement.

In case of grain movement analysis on the sieve surface were determined grain advances at the up and down movements on the sieve in the Δt time interval from grain reach on the sieve to sort (figure 7).

The total advance it was calculated as a sum of each movement advance:

$$a_j = \sum_{j=1}^{j-1} x_j + x_j \qquad (1)$$

where x_j is the advance.

Table 1 Values of velocity and acceleration

Time [s]	Kinematics parameters			Observations
	Position [m]	Velocity [m/s]	Acceleration [m/s^2]	
0.27	0.18014	-0.03892	0.00316	- grain's free fall
2	0.11742	-0.03474	0.01634	
2.93	0.08471	-0.00609	0.18698	- grain reaches the sieve surface, acceleration has maximum value
4	0.09919	0.0126	-0.00414	- grain moves up on the sieve - velocity and acceleration decrease
6	0.11849	0.00375	-0.00536	- grain moves down on the sieve - approximately constant acceleration
8	0.11634	-0.00375	-0.00255	
10	0.10401	-0.00884	0.00161	- grain moves up on the sieve - velocity and acceleration increase
12	0.09811	0.01019	0.00751	
14	0.12224	0.00938	-0.00214	- grain moves down on the sieve - velocity and acceleration decrease
16	0.13779	0.00348	-0.00322	
18	0.14047	-0.00268	-0.00389	- grain moves up on the sieve - velocity and acceleration have minimum values
20	0.1276	-0.00857	-0.00214	
22	0.10616	-0.00644	0.00456	- grain moves down on the sieve - low velocity and acceleration
23	0.10455	-0.00161	0.00483	- grain leaves the sieve (is sorted)

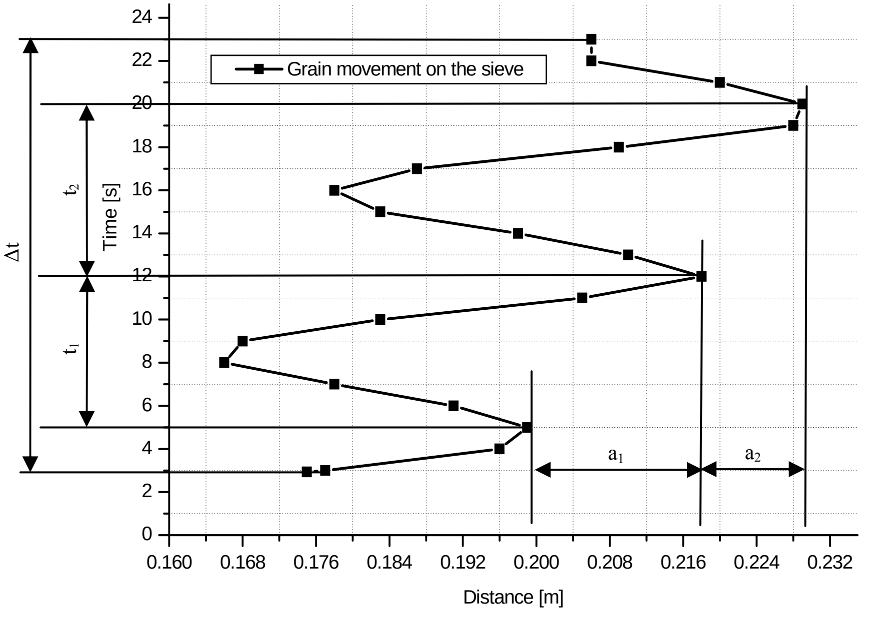


Fig. 7 Grain movements up and down on the sieve

The grain path during its movement from its fall on the sieve surface until its leave the sieve (sort) in absolute value is presented in figure 8:

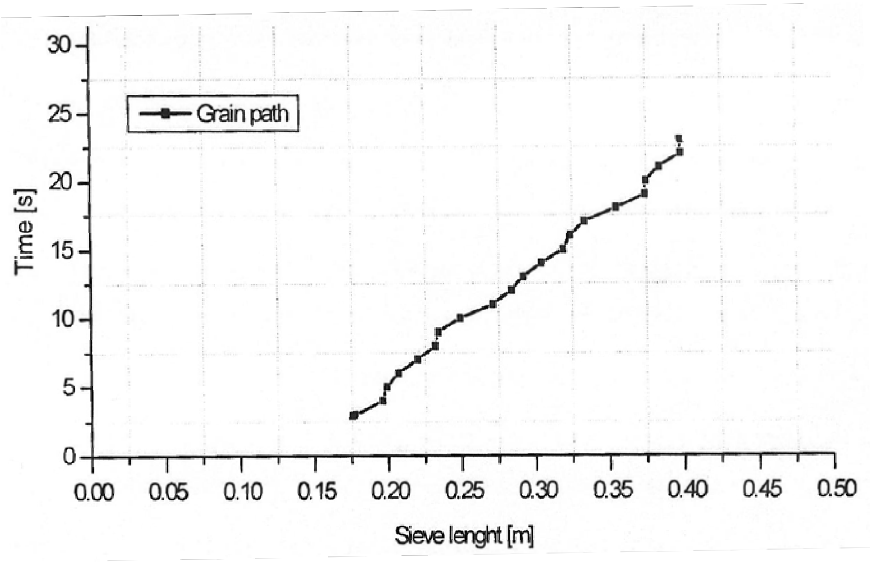


Fig. 8 Grains path on the sieve

CONCLUSIONS

Measurements were carried out with only one high speed video camera, allowing the grain movement analysis only on the longitudinal direction (up and down on the sieve); for grain movement analysis on transversal direction.

The shootings carried out with the high resolution camera offers a detailed analysis of grains movement on the sieves during sorting process, displaying of instantaneous position values of grain on sieve length and tracing trajectory of grain movement.

Besides grains advance movement up and down on the sieve, in sorting process appear other transversal movements on the sieves width due to grains collisions between them or collisions with sieve's separating shades.

Grains movement varies on the length of the sieve, so it is noticed grains high amplitudes in the first segment of the sieve, followed then by a uniform movement.

In grain's sorting process it can be seen that a large quantity of grains are sorted in the first half of the sieve where it creates a agglomeration of grains and where collisions between grains has a higher frequency.

Compared to grain movement on the sieve theoretical analysis, the video recordings reveal secondary movements caused by grain collisions between them and between the grains and sieves separating walls.

AKNOWLEDGEMENT

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.929:664.6/.7
Originalni znanstveni rad
Original scientific paper

SHEAR BIOYIELD STRESS AT PENETRATION WITH CONE OF SOME WHEAT FLOUR DOUGH

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SUMMARY

The paper presents results of experimental researches on bioyield stress to analysis of wheat flour doughs by cone penetration method. Were investigated dough from three types of wheat flour with and without added salt, at different masses of cone penetration (penetration speeds) and was determined variation of bioyield stress to shear of these dough, depending on time and on the depth penetration of cone. It was tested, by non-linear regression analysis using Microcal Origin program, experimental data correlation with variation power law type. It was found a very good correlation, assessed by values of R^2 correlation coefficient, which was in most cases analysed over 0.970 values. The results can be of real helpful of specialists in the bakery to optimize of operating regimes of equipment on the technological flow.

***Key words**: rheology, wheat flour dough, cone penetration, bioyield stress in shearing*

INTRODUCTION AND LITERATURE REVIEW

Rheological characteristics of dough are used by professionals in assessing its behaviour during mixing and processing processes and rational choice of constructive and functional parameters of the equipment performing these operations, [1,2]. Also, these characteristics are taken into account in assessing the quality of various types of flours and technological mixtures forming to match the technological to obtain quality finished products, [3–5].

Responsible in most of the flour quality and, therefore, the rheological characteristics of wheat flour dough is gluten content and quality, namely the main proteins from flour composition (about 85% of wheat proteins) [1,2,9,10,12].

In general, on gluten and flour quality may influence both pedological and climatic conditions where wheat was grown and harvested, and conditions and time storage, both of seeds and flour. Also, influences on quality of flour can may have wheat variety, its assortment, but and granularity of flour, and many other factors [9,15].

Today there are many methods and devices laboratory investigating the rheological behaviour of dough during mixing and processing processes, such as farinograph method, mixograph method, alveograph method, extensograph method, etc. [5,10,13].

Because many factors that may influence the quality of flour used in baking, these methods and devices are commonly used in laboratories of factories of bread, when brought a new batch of flour, but also to determine the influence on the dough behaviour of the various ingredients of recipe.

The analysis of acquired data and curves drawn by these devices can determine the rheological behaviour of dough in the baking process technology [5,13].

Rheological behaviour of wheat flour dough by dynamic oscillatory tests was done in [8], and the relationship between gas retention capacity and physical properties of dough in the papers [6,7].

There are tests for assessing the consistency and rheological characteristics of dough by penetrometer method with cone [3,4,5,11,13], the results obtained are encouraging.

Taking as a basis and taking into study experimental results obtained in testing of wheat flour dough with cone penetrometer in [3,4], it was performed to determine the shear bioyield tension of dough and its variations depending on the type of flour and time storage of flour.

MATERIALS, METHODS AND PROCEDURES

Knowledge of cone penetration resistance to assess of bioyield shear limit τ_c of materials subjected to experimental testing.

Taking into account the theoretical elements presented in the literature [10,12], on bioyield shear limit, but also the real characteristics of cone penetration used in experiments (fig.1) was calculated its lateral area in contact with the dough during the penetration process in the dough, based on cone size, determined using a digital calliper with 0.01 mm accuracy.

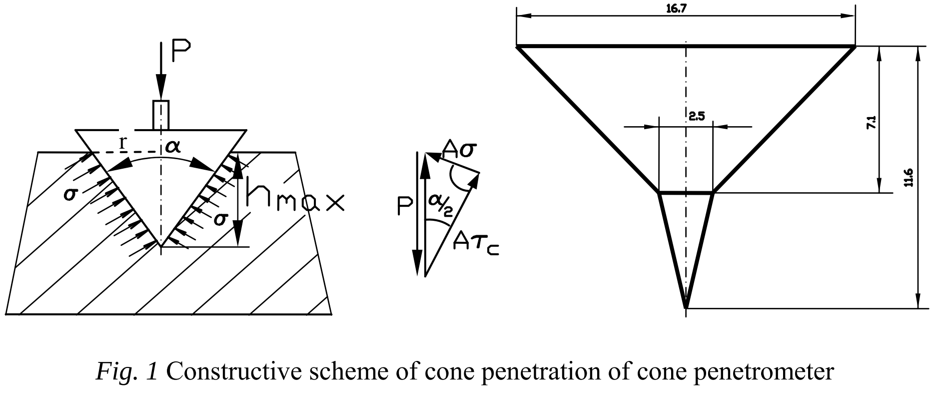

Fig. 1 Constructive scheme of cone penetration of cone penetrometer

Lateral area of contact between the material and cone penetration A, which is necessary to calculate the bioyield stress in shearing, is made of metal pin area and trunk area plastic cone, as follows:

$$A = A_{pin} + A_{con} \tag{1}$$

Lateral area in contact with the dough can be determined by the relationship:

$$A = \pi\, r\, G_{pin} + \pi\, G_{con}\,(R + r) \tag{2}$$

namely:

$$A = \pi\, h_{pin}^{2} \frac{\sin\frac{\alpha_1}{2}}{\cos^{2}\frac{\alpha_1}{2}} + \pi \frac{(h_{\max} - h_{pin})}{\cos\frac{\alpha_2}{2}} \left[(h_{\max} - h_{pin}) \mathrm{tg}\frac{\alpha_2}{2} + 2\frac{h_{pin}}{\cos\frac{\alpha_1}{2}} \right] \tag{3}$$

Corresponding force of bioyield stress in shearing, τ_c, is $A\cdot\tau_c$, parallel with pin generator, and with trunk cone generator, respectively. The force of normal stress σ is $A\cdot\sigma$ and is perpendicular to the cone generator in its two sections. The resultant of two forces must balance the pressure force P and be oriented on cone axis, at the depth h_{max}. Thus was obtained the scheme of forces composition, in figure 1:

$$P = \left(\frac{A_{pin}}{\cos\frac{\alpha_1}{2}} + \frac{A_{con}}{\cos\frac{\alpha_2}{2}} \right) \tau_c \tag{4}$$

From equation (4) determine the relationship of bioyield stress in shearing:

$$\tau_c = \frac{P}{A_{pin} \Big/ \cos\frac{\alpha_1}{2} + A_{cone} \Big/ \cos\frac{\alpha_2}{2}} \tag{5}$$

The experiments of [3] have used three types of wheat flour: FA-480A (improved), FA-650 and FN-1250, from wheat production of 2005, with moisture content of 13.96%, 14.26% and12.27%, respectively, and ash content between 1.23–1.30%, 0.65–0.70% and 0.40 – 0.48%, respectively. The dough was prepared from 300g flour and 165 g distilled water, and was mixed with a Millers Choice appliance, at speed of 150 – 160 rpm.

Measurements were performed with a penetrometer type SDM Apparechi Torino, using a standard plexiglas cone with peak angle of 90^o with dimensions in figure 1 and four masses of cone penetration (by using additional masses) 9.4 g; 14.1 g; 19.8 g and 27.2 g.

Knowing that 1 up = 0.1 mm, based on experimental data of paper [3], were calculated lateral areas of cone penetration and then bioyield stress values, using equation (5). The results are presented in Table 1.

Tab. 1 Bioyield stress in shearing (Pa) depending of time t (s), for the three types of wheat flour, to four masses of cone penetration

Nr.	Time t (s)	FA-480A				FA-650				FN-1250			
		Cone mass m (g)				Cone mass m (g)				Cone mass m (g)			
		9,4	14,1	19,8	27,2	9,4	14,1	19,8	27,2	9,4	14,1	19,8	27,2
1	5	2525.0	2109.4	2177.3	2556.6	3025.1	1582.2	1955.0	2136.0	3354.6	5031.9	2902.9	2653.0
2	10	1670.8	1729.8	1727.4	1998.4	1670.8	1272.9	1528.1	1688.5	2669.8	3125.9	2230.4	2034.9
3	15	1507.7	1568.4	1558.6	1791.9	1314.0	1204.5	1386.2	1509.6	2420.8	2758.7	1973.7	1817.4
4	20	1406.3	1476.6	1461.9	1665.9	1185.2	1099.0	1298.3	1408.3	2269.2	2518.2	1783.6	1675.6
5	25	1352.5	1392.2	1393.0	1586.8	1112.3	1043.5	1229.1	1340.7	2174.3	2349.5	1676.7	1583.2
6	30	1277.0	1358.2	1347.5	1539.1	1045.6	999.1	1180.7	1293.1	2062.1	2259.6	1578.7	1516.7
7	35	1241.5	1314.6	1310.2	1493.5	1010.0	971.0	1150.0	1255.3	1977.4	2153.6	1502.9	1466.6
8	40	1218.6	1293.5	1274.5	1456.0	976.1	950.7	1115.5	1219.1	1896.9	2073.5	1453.3	1412.9
9	45	1196.2	1262.8	1251.7	1432.0	943.7	924.5	1096.7	1198.1	1801.9	2016.0	1405.7	1373.0
10	50	1174.4	1233.2	1223.5	1414.2	912.9	905.6	1073.4	1170.9	1765.6	1978.8	1347.7	1345.7
11	55	1153.2	1214.0	1207.1	1390.9	898.0	887.2	1055.6	1151.1	1730.2	1942.6	1323.0	1318.8
12	60	1132.5	1195.2	1191.1	1373.9	883.5	869.4	1042.4	1125.5	1695.7	1907.3	1299.2	1298.3

RESULTS AND DISCUSSION

Based on results presented in Table 1, was drawn graphic variation of bioyield stress in shear for each of the three types of flour, each of the four masses of cone penetration, and then regression analysis of these was performed with the function power type (rel.6) in Office Excel program:

$$\tau_c = a \cdot t^b , \tag{6}$$

results being presented in figure 2 (a,b,c).

As shown in figures presented, the bioyield stress in shearing, in al three types of wheat flour, for each of the four masses of cone penetration has a descending trend, having values relatively higher at cone mass of 27.2 g, for FA-480 and FA-650 white flour, with a lower ash content (so with less coating) and cone mass of 14.1 g for FN-1250 black flour which has a higher ash content and therefore contains more coating.

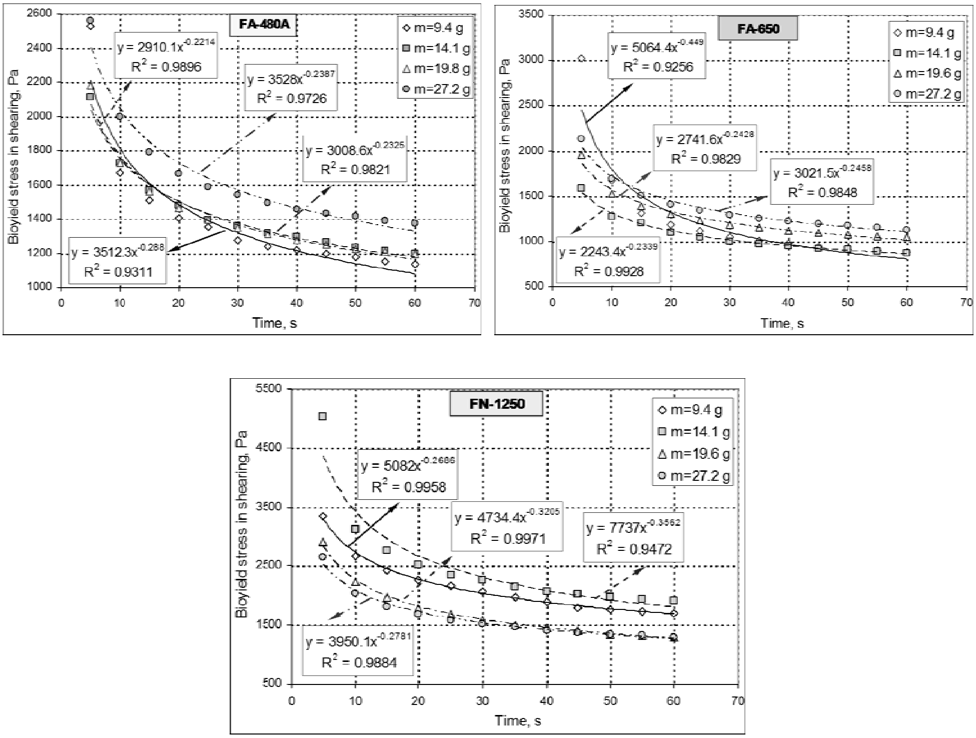

Fig. 2 Variation of bioyield stress in shearing for flours FA-480A, FA-650 and FN-1250, depending of time, for four masses of cone penetration

However, disposition of curves was not parallel there are some intersections of these, for four masses of cone penetration, which may be due to accidental causes.

However, the correlation coefficient R^2, presented, in most cases, values over 0.930 (except for one case), which expresses a good correlation of data obtained from experiments with power function regression. The values of coefficients of regression function, ‚a' and ‚b', depending by flour type and mass of cone penetration, so can be used to assess quality assortment of flour.

It is noted that the values of bioyield stress in shearing were located, generally, within 1-5 kPa, the stress having, obviously, higher values for higher masses of cone penetration. It can be seen, however, a slightly decreasing trend of bioyield stress in shearing with increasing of ash content in flour (the curve for FA-650 is below the curve for FA-480), after which the trend change (bioyield stress increases) because the curve for black flour FN-1250 is situated almost entirely above the other curves in all four masses of cone penetration (as shown in figure 3.

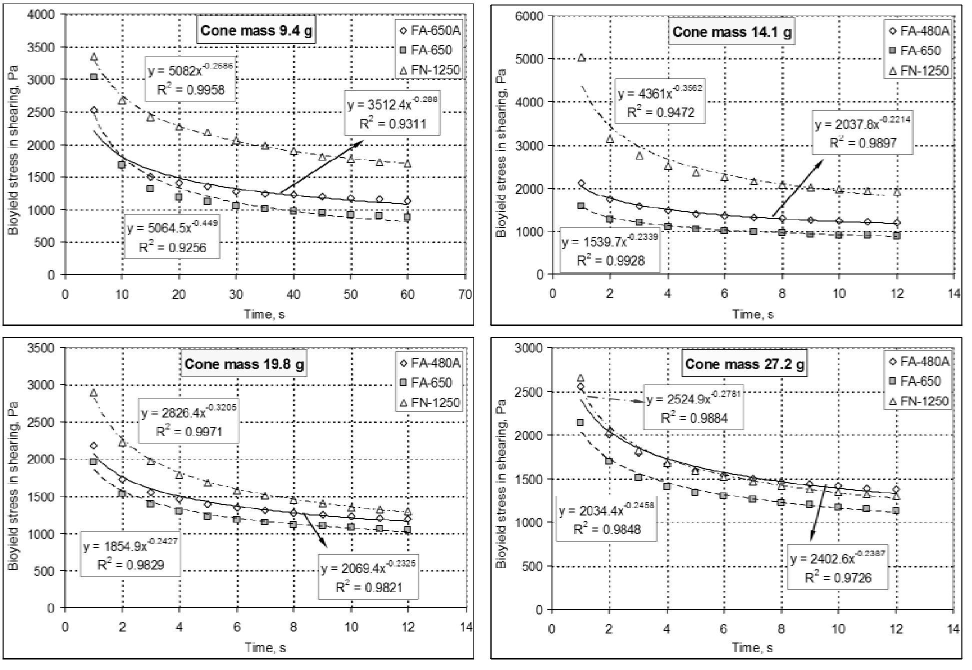

Fig. 3 Variation of bioyield stress in shearing for four masses of cone penetration, for three wheat flours FA-480A, FA-650 and FN-1250, depending of time

Further, to determine the influence of cone penetration speed in the dough on the variation of bioyield stress in shearing values graphic were drawn calculated values depending on the speed of penetration in dough (values taken from paper [3]), for the three types of wheat flour in four masses of cone penetration used in experiments. It was achieved, also, the regression of experimental data with power function and was determined the correlation between these based on correlation R^2.

Graphs of variation of bioyield stress in shearing τ_c (Pa), depending on the speed of penetration in dough, are represented in figure 4.

It is observed, also, a very good correlation of experimental data with power regression function, assessed by the high value of correlation coefficient R^2 (values very close to 1). It is noted the arrangement in ascending order of bioyield stress in shearing τ_c depending on the mass of cone penetration in all four types of flour, which expresses that evaluating the quality of flour can be made with sufficient accuracy using cone penetrometer.

However, the high correlation of experimental data with used regression function is graphic represented by parallel arrangement of variation curves of shear stress in relation to the penetration speed of cone in dough. It is estimated that the regression function coefficient values (‚a' and ‚b' of eq. 6) expresses the type of flour and mass of cone penetration, both for bioyield stress in shearing variation depending on time, as well as depending on the penetration speed cone.

The values of the coefficients ‚a' and ‚b' from relation (6), with correlation coefficient R^2 values are presented in Table 2.

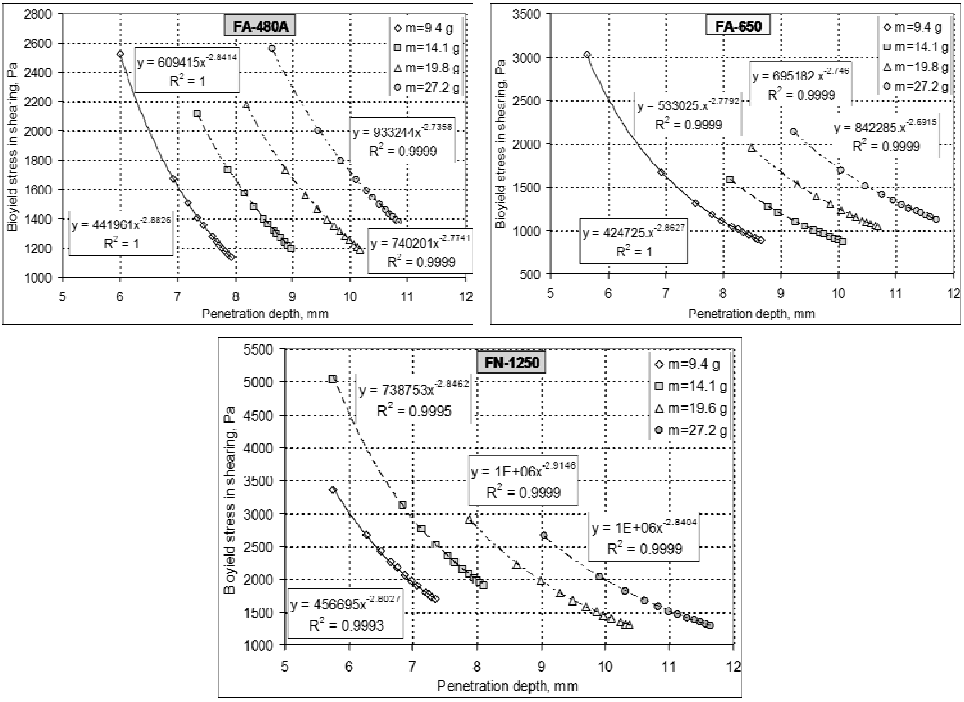

Fig. 4 Variation of bioyield stress in shearing for wheat flours FA-480A, FA-650 and FN-1250, depending on penetration speed of cone and correlation with regression function

Tab. 2 The coefficients ‚a' and ‚b' from rel. (6) and R^2 coefficient values, for the three types of flour analyzed

Cone mass, g	FA-480A			FA-650			FN-1250		
	a	b	R^2	a	b	R^2	a	b	R^2
9.4	3512.3	-0.288	0.931	5064.4	-0.449	0.926	5082	-0.269	0.996
14.1	2910.1	-0.221	0.990	2243.4	-0.234	0.993	7737	-0.356	0.947
19.8	3008.6	-0.233	0.982	2741.6	-0.243	0.983	4734.4	-0.321	0.997
27.2	3528.0	-0.239	0.973	3021.5	-0.246	0.985	3950.1	-0.278	0.988

Also, based on results obtained in papers [3,4], was determined variation of bioyield stress in shearing, at cone penetration, both for white flour FA-480A (improved) and FA-650, as well as for black flour FN-1250, depending on the period of storage (12 month after the first experimental determinations). It was calculated penetration speed of cone in dough, based on the values of penetration depth (mm) and time (s), and bioyield stress in shearing of dough (Pa). Measured and calculated results, above mentioned, are summarized presented in Table 3 and Table 4, for mass of cone of 14.1 g, considered representative of the determinations of the previous year.

There was a decrease of bioyield stress in shearing with decreasing of penetration speed, as the cone penetrates more and more in dough, in both years of experiments.

With these values was plotted graphically variation of shear stress depending on time, in two years of experimental measurements and regression analysis was performed of data with power regression function, the graphs obtained, but also values of equation coefficients and the correlation coefficient R^2 are shown in fig.5 – fig.7.

Tab. 3 Mean values of cone penetration depth h(mm), penetration speed (mm/s) and bioyield stress (Pa), depending on time t(s) for wheat flour FA-480A and FA-650, in two consecutive years (the same flour), for cone mass of 14.1 g

Time t(s)	Wheat white flour FA-480A						Wheat white flour FA-650					
	Penetration depth, (mm)		Penetration speed, (mm/s)		Bioyield stress, (Pa)		Penetration depth, (mm)		Penetration speed, (mm/s)		Bioyield stress, (Pa)	
	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007	2006	2007
5	7.35	5.95	1.470	1.190	2109.4	3878.3	8.13	5.55	1.625	1.110	1582.2	4707.7
10	7.88	6.60	0.788	0.660	1729.8	2880.5	8.78	6.02	0.878	0.602	1272.9	3751.8
15	8.15	6.85	0.543	0.457	1568.4	2586.5	8.95	6.07	0.597	0.405	1204.5	3664.5
20	8.33	7.05	0.416	0.353	1476.6	2379.6	9.25	6.38	0.463	0.319	1099.0	3176.8
25	8.50	7.20	0.340	0.288	1392.2	2238.9	9.43	6.52	0.377	0.261	1043.5	2983.9
30	8.58	7.28	0.286	0.243	1358.2	2168.6	9.58	6.62	0.319	0.221	999.1	2855.4
35	8.68	7.37	0.248	0.211	1314.6	2092.9	9.68	6.68	0.276	0.191	971.0	2781.8
40	8.73	7.52	0.218	0.188	1293.5	1974.8	9.75	6.75	0.244	0.169	950.7	2699.1
45	8.80	7.57	0.196	0.168	1262.8	1937.5	9.85	6.82	0.219	0.152	924.5	2619.6
50	8.88	7.63	0.178	0.153	1233.2	1894.0	9.93	6.85	0.199	0.137	905.6	2586.5
55	8.93	7.68	0.162	0.140	1214.0	1858.7	10.0	6.90	0.182	0.125	887.2	2532.6
60	8.98	7.73	0.150	0.129	1195.2	1824.4	10.08	6.93	0.168	0.116	869.4	2500.9

The analysis of graphs is found decreasing variation with time of bioyield stress in shearing, for the doughs prepared from the same flour, in the two years of experiments, but variation of bioyield stress is increasing with increasing of cone penetration speed. This phenomenon is valid to all doughs prepared from three wheat flour types.

However, the decrease of bioyield stress with time is more pronounced to the dough prepared from old flour, as the increase of bioyield stress with increase of cone speed is more pronounced to the same type of flour, as can be seen from graphs of fig.5-fig.7.

Also, is found a very good correlation of experimental data with used regression function, assessed by high values of R^2 (above 0.98)

This is valid both for bioyield stress variation depending on time, as well as for bioyield stress variation depending on dough penetration speed.

However, it should be noted that the bioyield stress in shearing by penetration with cone of dough increases with time storage of flour.

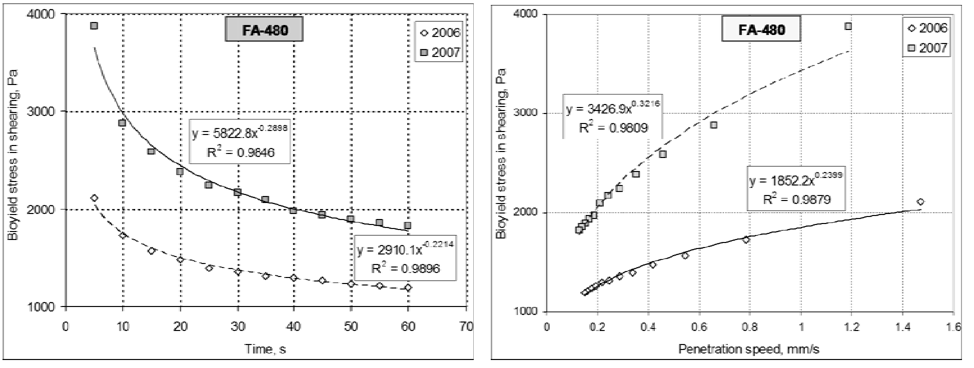

Fig. 5 Variation of bioyield stress in shearing for flour FA-480A, depending on time and penetration speed, in two consecutive years of experimental measurements

Tab. 4 Mean values of penetration depth of cone h (mm), penetration speed (mm/s) and bioyield stress (Pa), depending on time t (s) for wheat flour FN-1250, in two consecutive years (the same flour), for the cone mass of 14.1 g

Wheat white flour FN-1250													
Time t(s)	Penetration depth, (mm)		Penetration speed, (mm/s)		Bioyield stress, (Pa)		Time t(s)	Penetration depth, (mm)		Penetration speed, (mm/s)		Bioyield stress, (Pa)	
	2006	2007	2006	2007	2006	2007		2006	2007	2006	2007	2006	2007
5	5.75	5.03	1.150	1.006	4269.5	6089.0	35	7.78	5.90	0.222	0.169	1794.3	3971.9
10	6.85	5.30	0.685	0.530	2586.5	5327.2	40	7.88	5.92	0.197	0.148	1729.8	3934.2
15	7.15	5.53	0.477	0.369	2284.5	4754.3	45	7.95	5.97	0.177	0.133	1683.5	3841.7
20	7.38	5.65	0.369	0.283	2088.8	4482.5	50	8.00	6.02	0.160	0.120	1653.7	3751.8
25	7.55	5.73	0.302	0.229	1952.3	4311.1	55	8.05	6.07	0.146	0.110	1624.5	3664.5
30	7.65	5.80	0.255	0.193	1879.8	4167.4	60	8.10	6.12	0.135	0.102	1596.1	3579.8

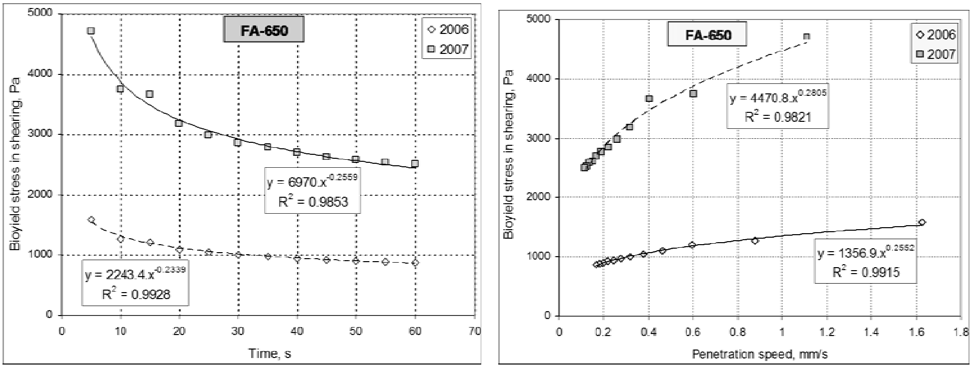

Fig. 6 Variation of bioyield stress in shearing for flour FA-650, depending on time and penetration speed, in two consecutive years of experimental measurements

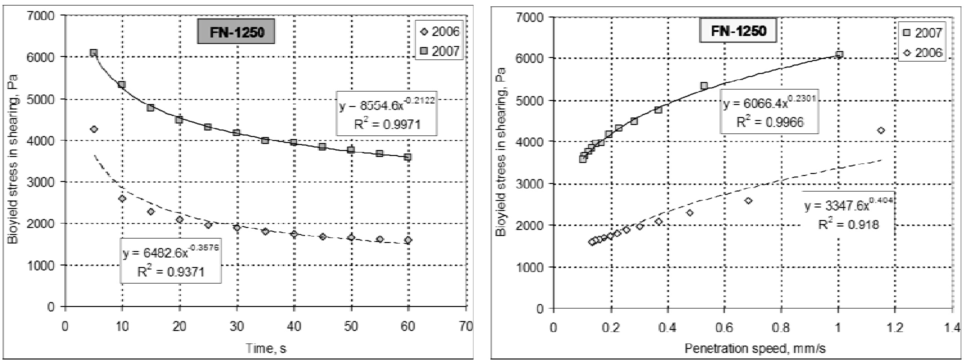

Fig. 7 Variation of bioyield stress in shearing for flour FN-1250, depending on time and penetration speed, in tow consecutive years of experimental measurements

CONCLUSIONS

There is a decreasing trend of shear stress depending on time, both in fresh flour, as well as in old flour (time storage of 12 month), while the shear stress increase on cone penetration speed in dough, also, in both types of flour (fresh and old) (see fig.5 and fig.6). From those before presented it was found that variation of bioyield stress in shearing depending of cone penetration speed is proportional to the mass of cone, shear stress decreased with increasing of penetration speed in all four masses of cone, as well as for all analyzed three types of flour (FA-480A, FA-650 and FN-1250) (see fig.2 and fig.3).

Although there is a decreasing tendency of dough shear stress depending on penetration (cone action on dough), for all four of the cone masses, as well as for the three types of flour (see fig.3), there are, however, overlaps and intersections of variation curves, which leads to the consideration that flour has not yet a homogeneous quality, but the phenomenon can be attributed to other causes (more or less objective).

Estimating of bioyield stress in shearing can be used in assessing of forces needed for detachment of dough of the mixing arms or dough kneading tank walls, so in the assessment of power consumed in process and in the choice of electric motor drive.Knowing the shear stress of dough can be used, also, to estimate the necessarily forces for mixing dough divide into pieces, and mechanical processing stages of the baking technological process.

However, knowledge of shear stress can be used in the design and construction machinery typical for mixing and processing operations (divide, modelling, notching).

ACKNOWLEDGEMENT

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDC 621.798:631.564
Pregledni rad
Review paper

BIODEGRADABLE MATERIALS USED IN THE AGRICULTURAL PRODUCTION SYSTEMS – APPLICATIONS AND TYPOLOGY

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SUMMARY

The food packaging industry nowadays relies on petrochemical-based plastics because of their wide availability at a relatively low price. Besides the environmental issues, crude oil resources are decreasing while their price is increasing. As it is almost impossible to reduce the consumption of plastic products, we will analyze the possibility of producing food packaging, especially laminate films from alternative raw materials which, unlike fossil fuels, are both eco-friendly and renewable. The most common biodegradable and compostable synthetic polymers are lignin, cellulose and starch. These are anticipated to have equal or even better barrier properties and to be easily manufactured through injection moulding, sheet extrusion, blow moulding, thermoforming, film forming and other processes and technologies currently specific to traditional plastics. Being biodegradable and compostable the use of bioplastics solves both the environmental problem of waste disposal and the financial problem of recycling. At the moment, bioplastics covers only 5-10% of the plastic market, the biggest drawback being the cost competitiveness to the traditional plastics – bio-based polymers have wider applications only in the medicine field where the function is more important than the cost. This paper aims to give a complete view over the bioplastics and over the applications than can be used in agricultural systems. It provides an overview over the bioplastic materials and defines which applications are better suited for each one regarding their properties. Having a broader look over these materials they might find their deserved way in the agricultural industry.

Key words: *food packaging, bioplastic, agriculture, renewable resources, biodegradability*

INTRODUCTION

The limitation of resources, especially petroleum, is a well-known issue which affects a wide range of the industry. A global preoccupation is to generate electricity, thermal energy and fuels through regenerating or alternative forms of energy such as solar energy, hydro energy, wind energy or renewable biomass from agriculture and forestry. A percentage of renewable energy consumption is shown in Figure 1. In addition, the field of biopolymers produced from renewable agricultural and forest resources (biomass), also called bioplastics, is gaining in popularity. This means also more work respectively a higher income to those involved in agriculture. The aim is to bring in front solutions that are both environmentally friendly and with similar or even better properties.

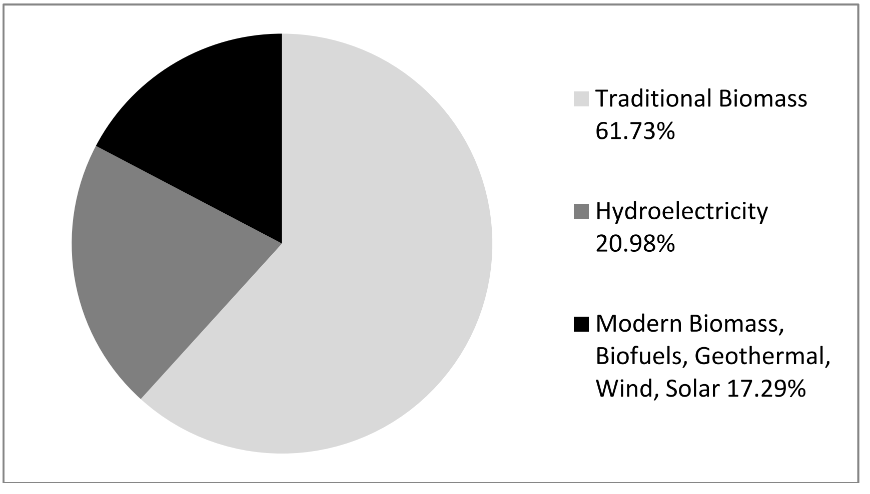

Fig. 1 World consumption of renewable energy [Global Status Report, Renewable 2011]

The market is demanding for materials that are more natural, disposable and potentially biodegradable as well as recyclable [Cha, D.S., Chinnan, M.S., 2004]. The wide range of applications where plastic is currently used underlines the need of developing not of just one polymeric system but to provide a solution to each unique and individual application [Lakshmi S. Nair, Cato T. Laurencin, 2007]. With bio-based polymers, new functionalities are being achieved.

Therefore it becomes necessary for the companies to show interest in food-packaging systems in which the polymer matrix has low environmental impact [Jin T., Zhang H., 2008] and to find ways of improving their productivity in terms of maintaining safety, using sustainable materials in packaging, implementing flexible and standardized technology, all together at competitive prices [Cheruvu, P. Kapa, S., Mahalik, N.P., 2008]. For this matter Arora and Kempkes [Arora V.K, Kempkes M., 2008] are outlining the huge gap between research in the field of food processing technologies and its implementation in the industry.

But this new trend brings also a lot of confusion in the means of terms. New terms such as bioplastic, biodegradable, compostable, recyclable are not well defined and the producers take advantage of this fact to selling their green products that are not always the most environmentally friendly. Further we wish to differentiate this terms and to present a review of biodegradable materials and some processing aspects in food industry especially packaging in order to bring the academic world and the industry to a collaborative work.

MATERIALS AND METHODS

In terms of biodegradable and compostable the American Society for Testing and Materials (ASTM) defines the three most significant standards developed by Subcommittee D20.96 and they are: ASTM D6400 04 Standard Specification for Compostable Plastics, ASTM D6868 - 03 Standard Specification for Biodegradable Plastics Used as Coatings on Paper and Other Compostable Substrates, and the ASTM D7081 - 05 Standard Specification for Non-Floating Biodegradable Plastics in the Marine Environment [ASTM International]. According to them there a biodegradable plastic is as a plastic that degrades because of the action of naturally occurring microorganism such as bacteria, fungi and algae. A compostable plastic is a plastic that undergoes degradation by biological processes during composting to yield carbon dioxide, water, inorganic compounds and biomass at a rate consistent with other known compostable materials. Therefor not all biodegradable materials are compostable.

Both traditional plastic and bioplastic can be either biodegradable or non-biodegradable. The difference between these two types of plastic is their source of origin. While traditional plastic is made out of petroleum, bioplastic is made out of renewable resources.

According to their origin, bioplastic can be differentiated as shown in figure 2.

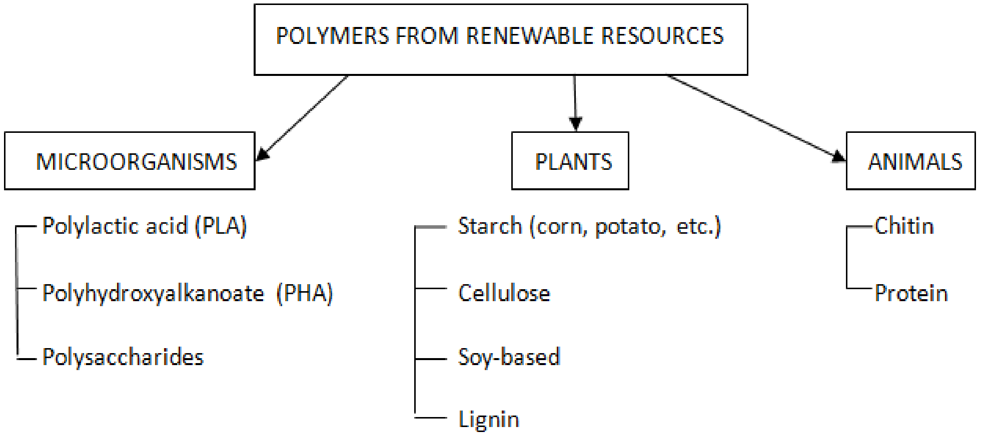

Fig. 2 Polymers from renewable resources according to their origin

According to the way they are obtained, polymers from renewable resources can be classified into three groups [Long Yu, 2009]: (1) synthetic polymers from bio-derived monomers; (2) polymers from microbial fermentation; (3) natural polymers, figure 3.

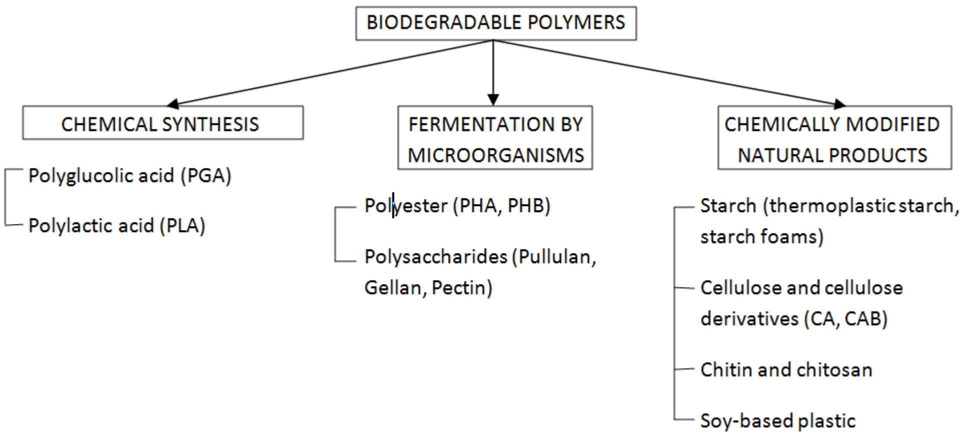

Fig. 3 Polymers from renewable resources by the way they are obtained

Polylactic acid (PLA) or polylactide (PLA) is a thermoplastic aliphatic polyester derived from renewable resources, such as corn starch (in the United States), tapioca products (roots, chips or starch mostly in Asia) or sugarcanes (in the rest of world). Because of its excellent processability, biocompatibility and biodegradability it has become the most popular packaging material of all renewable resource polymers with a rate of over 40% of all bioplastics used in packaging [www.plastemart.com]. NatureWorks LLC began its work in 2001 as a subsidiary of Cargill Dow and is the biggest PLA facility in the world. Because of its versatile material properties such as adjustable Young modulus from 350 to 2800 MPa, melting 150 ^{o}C and degradation time 18-24 month [M. Flieger, et. al., 2003] , this bioplastic can be used in various applications such as bags, geotextiles, interior and exterior furnishing, film barrier coating but it is mainly preferred in the packaging industry.

Polyesters such as *Polyhydroxyalkanoates (PHA)* or *Polyhydroxybutyrate (PHB)* are both produced in nature by a wide variety of bacterial fermentation. PHA and PHB can be either thermoplastic or elastomeric materials with melting points ranging from 40 to 180 ^{o}C. With a tensile strength of 40 MPa it has similar properties to those of polypropylene. It is biocompatible, 100% resistant to water, biodegradable and also thermoplastic process ability. The most common producer of these alkanoates is Metabolix with its product Mirel®.

Cellulose is one of the most abundant biopolymers on earth. It is the major constituent of plant cell walls, and more than half of the organic carbon on earth is found in cellulose. Cellulose was first discovered in 1838 by the French chemist Anselme Payen and is isolated from its crystalline state in microfibrils by chemical extraction [Encyclopædia Britannica Online]. It is fusible and soluble in hydrogen bond-breaking solvents such as N-methylmorpholine-N-oxide. Cellulose-based bioplastics are typically chemically-modified plant cellulose materials such as cellulose acetate (CA). Common cellulose sources include wood pulp, hemp and cotton. There can be distinguished two main groups of cellulose-materials: cellulose composites suitable only for reinforcement and thermoplastically processable cellulose derivates which can be used for extrusion and molding. The first of its applications was cellophane films and up to date the most common use of cellulose is to make flexible foils. Due to its low permeability to air, oils, greases, bacteria and water it makes it very useful for food packaging. There can be distinguished two main groups of cellulose-materials: cellulose composites suitable only for reinforcement and thermoplastically processable cellulose derivates which can be used for extrusion and molding.

Lignin is second to cellulose as the most abundant natural polymer on earth. Lignin is a complex chemical compound, a cross-linked polymer that forms a large molecular structure. Most commonly derived from wood or crops it is an integral part of the cell wall where it forms a tridimensional structure, a matrix, which gives mechanical strength to wood, basically supporting the tree's structure. Industrial lignin is mostly obtained as a co-product of the manufacture of cellulose pulp during papermaking and biomass fractionation. New applications are emerging for specialty, sulfur-free lignin in diverse areas, principally as sustainable alternatives to nonrenewable products, such as phenolic and epoxy resins, and isocyanates. This is in addition to industrial efforts that aim at using lignin as the principal component of thermoplastic materials. The latter represents an activity for which little published information exists so far. The ability for lignin to make significant impact in these areas, however, depends on its availability in industrial quantities as a high-purity product, preferably in a sulfur-free form.

Starch is a major plant storage from glucose. It consists of a mixture of 20-30% amylose and 70-80% amylopectin. Starch is abundant in plants such as maize, wheat, potato, rice, and pea, and is thus cheap and readily available. Biodegradation of starch-based polymers is due to enzymatic attack at the glycosidic linkages between the sugar groups. The thermoplastic starch (TPS) has high moisture uptake, it is water solvable, its mechanical properties change in time and has high shrinkage after it is processed by injection moulding [Tabi T., PhD thesis booklet, 2010]. Although there are numerous literatures dealing with the investigation of TPS, there is almost no information about the effect of the high plasticizer content of TPS on the processing, and also there is no information about the effect of the holding pressure – like a shrinkage decreasing parameter – on the high shrinkage of TPS [Wiedmann, W., Strubel, E.,1991]. Starch can be applied in four different technological modes that result in diverse groups of products:

- Starch composites with low amount of starch (≈10-20 %)
- Starch composites with medium amount of starch (≈40-60 %)
- Starch composites with high amount of starch (≈90 %)
- Foamed starch

CONCLUSION

Due to ambiguous definitions given to the term "bioplastics", it is impossible to analyze the size of the total market. Still, it can be estimated that the worldwide production capacity is around 327,000 tons [NNFCC Renewable Polymers Factsheet], but at the moment, they represent only 0.1% of the global plastics consumption [www.hgca.com]. The Committee of Agricultural Organization in the European Union (COPA) and the General Committee for the Agricultural Cooperation in the European Union (COGEGA) have analyzed the possibilities of using bioplastics in different sectors of the economies across Europe, the result being shown in the figure 4.

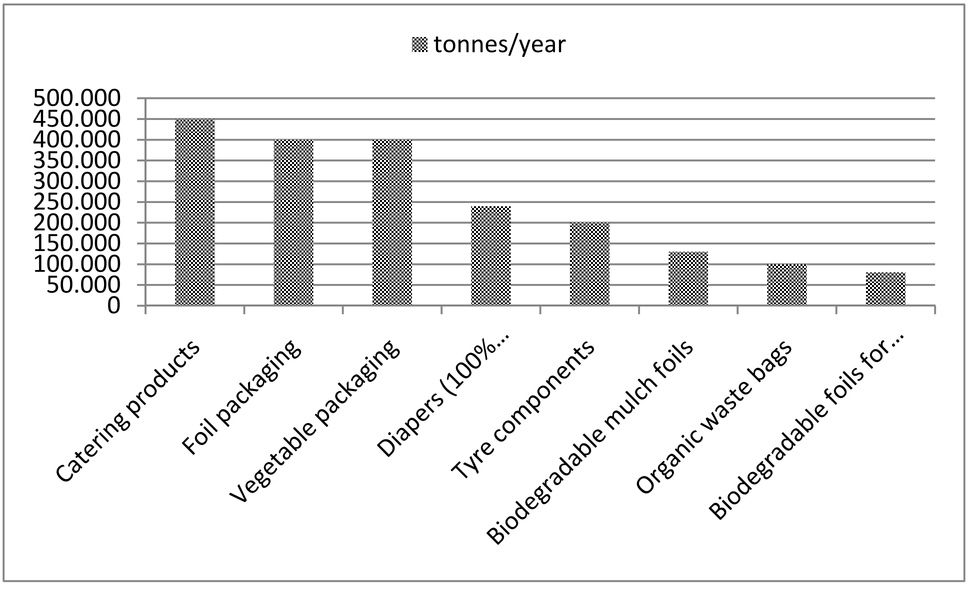

Fig. 4 Posssibilities of using bioplastic as analyzed by COPA and COGEGA

Between 2000 and 2008, the global consumption of biodegradable plastics based on starch, sugar and cellulose has increased by 600% [www.ceresana.com]. Also, it has been predicted by The UK's National Centre for Biorenewable Energy, Fuels and Materials (NNFCC) that the worldwide annual capacity would grow to 2.1 million tons by 2013 [NNFCC Renewable Polymers Factsheet]. This will still represent just a small part of the total plastics market, the major drawback being the gap between research and applying it in industries [Mahalik, N.P., Nambiar A.N., 2010], especially because bioplastics are generally considered just a substitute for traditional ones, as they are still more expensive. Regarding the cost effectiveness, the whole lifecycle of bioplastics should be taken into consideration, not just the costs of producing them, as these are not the only ones involved. For example, compostable agricultural films are more expensive than traditional ones, but the costs of collecting and recycling them are reduced to zero.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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EXPERIMENTAL RESEARCHES ON WORK OPTIMIZATION OF OIL PRESSES

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SUMMARY

Oil pressing (also known as expeller pressing) is a mechanical method for oil extraction from raw materials. The extraction of oil from seeds or plant parts, is accomplished by mechanical pressing, sometimes followed by chemical extraction, because the mechanical pressing alone does not remove all the oil from the seed. Optimization of mechanical oil presses exploitation involves adjusting the constructive and functional parameters, so that power consumption for compression to be minimal and the degree of separation of oil to be larger, in terms of processing capacity (productivity) as large as possible. This paper presents the results of experimental researches conducted in the laboratory, for which was used a continuous mechanical press PU-50 type, with two exhaust ends, having a processing capacity of 40 kg/h, oil yield of 40% and a supply tank capacity of about 37 dm^3. The material used for the experiments were sunflower seeds with following characteristics: oil content 36%, hectoliter mass 41 kg/hl and shell content 26%. Independent adjusted parameters during the experiments were: cross-section area at the exit of the cake from the pressing chamber, respectively the pressure from the pressing chamber. Thus, were utilised three different nozzles, with diameters of 8, 10 and 12 mm. Processing the experimental data allowed the identification of domain in which constructive, functional and material parameters must be found so that the residual oil yield to be lowest, power consumption at pressing to be smallest and productivity of the press to be as highest possible.

Key words: *Continuous mechanical press, pressing, power, press cake, oil recovered, nozzle*

INTRODUCTION

Sunflower (*Helianthus annuus L)* is a plant of composite family belonging to the large family of flowering plants that are mainly herbs and shurbs. The sunflower is grown throughout the world due to his relatively short growing season. Out of the total global production of oilseeds (404 million tons in 2008/2009), sunflower seed represents only 8%. The greatest seed production is of soybean (55%), followed by rapeseed (14%) and cottonseed (10%). The seeds of sunflower are rich in oil (about 50 wt. %) and it is considered to be a potential source of proteins for human consumption. This is due to its high ratio of polyunsaturated/saturated fatty acids and the high content in linoleic acid (Ohlson, 1992; Isobe et al., 1992).

About 90% of sunflower seed produced is being used for oil extraction (Yoyock et al., 1988). The oil extracted from sunflower seeds is a good source of vegetable oil for cooking, manufacturing of margarine, paints, soaps and cosmetics. Moreover, Zafforoni et al. (1978) found that sunflower, apart from the oil extracted from it for direct human consumption, it can also be used as a substitute for diesel oil in internal combustion engines. Vegetable oil is extracted from oilseed plants wich can be annual plants, such as soybeans, corn, cottonseeds, groundnuts, rapeseeds, melon seeds and sesame seeds etc. (Frank, 1998; O'Brien 1998) or perennial plants, such as olives, coconuts, cashew and palm kernel. (Atiku şi alţii, 2004)

Oil is obtained from oilseed by either solvent extraction or mechanical expression or the combination of the two processes. Mechanical pressing is used for oil recovery up to 90-95%, while solvent extraction is capable of extracting 99%. Mechanical pressing is the most popular method of oil separation from vegetable oilseeds in the world (Mrema&McNulty, 1985). For mechanical expression, hydraulic or screw press is employed.

The conventional method of oil extraction suggests that oilseeds must be thermal pretreatments (cooking) before pressing, which is called the hot pressing (Rasehom et al., 2000; Bargale et al., 1999, 2000). More recently, the cold pressing for oil extraction, which needn't be cooked prior to pressing, is very popular in many countries. The main reason for popularity of the cold pressing is that it yields limpid color and fruity oilseed oil with lower phosphorus and fatty acid (Rasehom et al., 2000; Zheng Xiao et al., 2004). However, compared to the hot pressing, the cold pressing is inefficient with lower throughputs and higher residual oil contents of the cake.

Mechanical oil expellers are popular because these equipments have a simple and sturdy construction, can easily be maintained and operated, can be adapted quickly for processing of different kinds of oilseeds, and the oil expulsion process is continuous, the product being obtained within a few minutes from the start of the processing operations. However, the mechanical screw presses are relatively inefficient, leaving about 8-14% of the available oil in the cake (Srikantha, 1980). Thus, in order to reduce the demand and supply gap of vegetable oils in developing countries, it is needed to develop more efficient mechanical screw presses.

Considerable efforts have been made in the past to improve the oil extraction efficiency of screw presses. Most of them have focused on optimization of process variables such as applied pressure, pressing temperature and moisture conditioning of the feed samples (Ohlson, 1992). The degree of influence varies with kind of oilseeds and method of oil expression (Akinoso, 2006). Effects of some of these parameters on yield and quality of oil expressed from sunflower using expeller were investigated.

The results of a study concerning the expression characteristics of sunflower (Singh et al., 1984) indicate that the effect of moisture content was the most significant. In addition, the effects of applied pressure, temperature and pressing time were also significant. The optimum pressing conditions for maximum oil recovery were pressing of the whole seed at 70 MPa with 6% moisture content at a temperature of 20ºC.

A small press of nominal capacity (40 kg/h) was evaluated for cold pressing of undecorticated sunflower seed (Prinsloo and Hugo, 1981). It was observed that narrower choke openings gave lower residual oil in cake, while the press throughput remained virtually unchanged with variation in choke opening. Higher shaft speeds increased the throughput but also increased the residual oil in cake.

For a Simon Rosedown Mini-40 screw press was investigated the effects of shaft speed, choke opening and seed pretreatments on pressing performance for canola seed (Vadke and Sosulski, 1988).The press throughput and oil output both reached a maximum at a seed moisture content of 5% while the residual oil showed a continuous increase with an increases in seed moisture contents. As the choke opening and the shaft speed were lowered, the maximum pressure increased while the press throughput and residual oil both decreased.

Olayanju (1992) observed that the yield of oil from groundnut increases with a reduction in clearance. Improvement in the mechanical extraction equipment and techniques through proper conditioning can raise oil recovery from 73% to 80% for rapeseed and groundnut (peanut) and from 60% to 65% for cotton seeds (Pathak et al., 1988). Efforts are been made to improve the performance of oil expellers through modifications in press design and by optimization.

This study set out to evaluate the effect of choke opening on oil extraction from sunflower seeds using a screw press. The characterization of extraction performance was observed by determination of oil extraction yield, specific mechanical energy and content of impurities.

THEORETICAL ELEMENTS

The pressing process of oleaginous material take place under the influence of compressive forces which arise in mechanical presses. Pressing process can be compared to a capillary filtration process, expressed by the relation [1]:

$$V = \frac{\pi \cdot p \cdot d \cdot t}{128 \cdot \eta \cdot l} \quad (\text{m}^3)$$

where: V-separated liquid volume (passing through the capillary), (m^3); p-applied pressure, (N/m^2); d- capillary vessel diameter, (m); η-oil dynamic viscosity, (Pa·s); l- capillary vessel length to be covered by separate oil, (m); t- during of application of pressure, (s).

From the above relationship results that the extraction oil process can be positively influenced if p, d and t values increase or if l and η values decrease.

Pressure ratio (representing the reduction of the material subdued to pressing) is calculated with the relation:

$$\varepsilon = \frac{V_i - V_f}{V_i}$$

where: V_i –the initial volume of the material, (m^3); V_f –the final volume, (m^3).

Press volume flow rate can be evaluated by using the relation:

$$Q_v = \frac{\pi}{4} \cdot (D^2 - d^2) \cdot (s - \delta) \cdot (1 - \varepsilon) \cdot n \cdot k \cdot 60 \ \text{(m}^3\text{/h)}$$

where: *s*-represents the auger spire pitch, (m); δ-thickness of the auger spire, (m); *D*-outer diameter of the auger spire, (m); *d*-inner diameter of the auger spire (of the auger shaft), (m); *n*-the auger rotative speed, (rpm); *k*-coefficient taking into account the material flowing back through the spire extremities, as well as the incomplete feed with material, (k=0,2÷0,35).

The power necessary to operate the press can be evaluated by using the relation:

$$P_p = \frac{P_{tr} + P_{pres} + P_{fr} + P_{cap}}{\eta_{tm}} \ \text{(kW)}$$

where: P_{tr} – represents the necessary power for transporting the material from the feeding chamber to the exhaust head, (kW); P_{pres} – necessary power for pressing the material, (kW); P_{fr} – necessary power for overcoming the frictions between the auger spire and the material, (kW); P_{cap} – necessary power for pushing the material through the exhaust space in the press, (kW); η_{tm} – mechanical transmission yield (output).

Power necessary for transporting the material is calculated with the following relation:

$$P_{tr} = \frac{F_r \cdot v}{1000} = \frac{\pi \cdot (D^2 - d^2) \cdot \Psi \cdot \gamma \cdot l \cdot g \cdot v}{4 \cdot 1000} = \frac{\pi \cdot (D^2 - d^2) \cdot \Psi \cdot \gamma \cdot l \cdot g \cdot s \cdot n}{4 \cdot 1000 \cdot 60} \ \text{(kW)}$$

where: F_r – represents the force resisting to the material advancing along the press auger, (N); *v* – mean speed by which the material moves along the press auger, (m/s); ψ – represents the coefficient of admission for the press section; *l* – length of pressing chamber, (m); *g* – represents the gravity acceleration , (m/sq.s);

Necessary power for pressing the material can be expressed by the relation:

$$P_{pres} = \frac{L_{pres} \cdot n}{1000 \cdot 60} = \frac{(1 + 2 \cdot \beta) \cdot p \cdot \varepsilon \cdot V_i \cdot n}{3 \cdot 1000 \cdot 60} \ \text{(kW)}$$

where: L_{pres} -the mechanical work done for pressing the material, (J); p - represents the pressure performed by the auger, which is exerted on the material, (Pa); β - represents the coefficient of the side pressure.

Power necessary for overcoming the frictions between the auger spire and material can be evaluated by using the relation:

$$P_{fr} = \frac{M_f \cdot \omega}{1000} = \frac{M_f \cdot \pi \cdot n}{30 \cdot 1000} = M_f \cdot \frac{n}{9550} = \frac{2 \cdot \pi \cdot \mu \cdot p \cdot \left(R_2^3 - R_1^3\right)}{3} \cdot \frac{n}{9550} \text{ (kW)}$$

where: M_f - the friction torque (moment) for the whole active cross surface of the auger spire, (Nm); R_2-outer radius of the auger spire, (m); R_1 – inner radius of the auger spire (of the auger shaft), (m).

Power necessary for pushing the material through the exhaust space is expressed with the relation:

$$P_{cap} = \frac{p \cdot \pi \cdot d_c^2 \cdot l_c \cdot n}{4 \cdot 1000 \cdot 60} \text{ (kW)}$$

where: l_c – length of exhaust canal, (m); d_c – exhaust canal diameter, (m).

MATERIAL AND METHODS

The experiments were conducted using whole sunflower seeds supplied by Giurgiu county, Romania. The most important characteristics of the seeds are: oil content of 36%, moisture content of 4,9%, shell content of 26,69% and the mass of 1000 seeds of 72,65g. The mean values for the dimensions of the seeds are: length of 11,0853mm, width of 5,7463mm and thickness of 3,7126mm. The seeds were subjected to a selection process using a SS-02 seeds selector with a capacity of 100 kg seeds/h. The seeds selector separated the impurities from the seeds, at the end of this process resulting the percent of separated impurities of 23%. In order to determine the oil content of the seeds it was used a Nahita Vortex stirrer and an UFE 400 MEMMERT universal oven, equipments of the Faculty of Chemistry laboratory from “Politehnica” University of Bucharest. Using the same MEMMERT universal oven, the moisture content of the sunflower seeds was measured. A KERN 572 analytical scale with maximum capacity of 5 kg and a digital caliper beam were also used for characteristical determination of the seeds.

For the pressing operation of the seeds was used a small capacity mechanical continuous press, with two exhaust ends, the PU-50 screw press produced by STIMEL Timişoara.

The PU-50 screw press is a press for cold pressing of the seed, that means that seeds aren’t subjected to the roasting and dehulling processes before the pressing. The performances of the screw press are shown in the table 1.

The two exhaust ends of the screw press are equiped with 300W heating electrical resistances. The resistances are used to increase the temperature of the pressing chamber who will help to a better expulsion of the oil from the press, due to the decrease of oil viscosity. The screw of the press have constant diameter and variable pitch, as it shown in the figure 2.

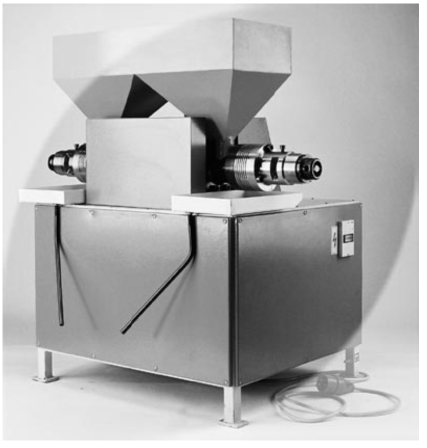

Fig. 1 Screw oil press PU-50

Tabel 1 Performance of PU-50 oil press

Performance	**PU-50**
Productivity (l/h)	16-19
Processing capacity (kg/h)	38-42
Oil yield (%)	38-42%
Supply tank capacity (dm^3)	aprox. 37
Electrical motor power (kW)	3

Fig. 2 The screw of PU-50 oil press

The exhaust ends of the press are provided with nozzles which determine the thickness of the evacuated cake. For the variation of the choke opening, the press is equiped with a set of nozzles with internal diameter between 3 and 12 mm.

For the experiments were also used the following equipments: 60K20NL KERN digital scales with maximum capacity of 60 kg (to measure weight), stop watch (to measure time) and wattmeter bridge QN 10 (to measure the power).

Prior to the start of the experiments, the screw press was warmed using the heating electrical resistances for 20-30 minutes, until the barrell temperature reached to 80-90ºC. Once this temperature was obtained, the resistances was deconected and we started to feed the hopper with sunflower seeds. The samples of seeds were weighed before loading into the screw press. After the pressing process, the cake and the oil resulted were also weighed.

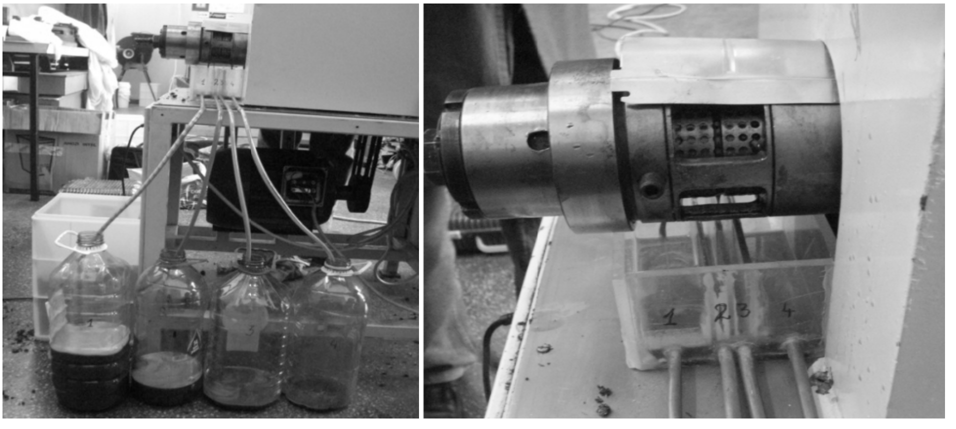

Fig. 3. The collection of extracted oil in the compartmented tray

For oil collection it was used a tray with four compartments distributed along the barrel press, as it can be observed in figure 3. During the experiments the pressing time and the power consumption were measured. The experiments were conducted in three stages, in each stage using a different nozzle for the exhaust ends of the press, which is equivalent with the variation of the pressure from the pressing chamber. The nozzles used for experiments were the nozzle with diameters of 8, 10 and 12 mm. The oil obtained from the experiments was further subjected to a decantation process for 24 hours in order to separate the foot (the impurities) from the oil. The inlet flow rate of the seeds (Q_s) and the specific mechanical energy (SME) were calculated with the following relations:

$$Q_S = \frac{M_S}{t_p} \quad \text{and} \quad SME = \frac{P}{Q_S}$$

where: M_s- the weight of the seeds (kg); t_p- the time of pressing (h); P- the measured power (W); Q_s -the inlet flow rate of the seeds (kg/h).

RESULTS AND DISCUSSION

In table 2 are presented the results measured and calculated from the pressing process of a 15 kg sunflower seeds.

Table 2 Pressing results of a 15 kg sunflower seeds; C1- the first compartment of the tray (the compartment near the end of the pressing chamber); C2- the second compartment; C3- the third compartment; C4- the fourth compartment (the compartment located near the feeding area of the press)

Nozzle	Φ=12mm	Φ=10mm	Φ=8mm
Press cake (kg)	10.103	9.894	9.685
Oil recovered (kg)	4.872	5.025	5.177
Oil recovered C1 (kg)	2.842	2.817	2.791
Oil recovered C2 (kg)	1.431	1.760	2.088
Oil recovered C3 (kg)	0.400	0.339	0.277
Oil recovered C4 (kg)	0.199	0.110	0.021
Inlet flow rate (kg/h)	40	38	36
Specific mechanical energy (Wh/kg)	39.46	40.24	41.10

After the decantation process, the oil and the foot obtained were weighed and the results are presented in the following table:

Tabel 3 The results of the decantation process; Foot=Impurities

Nozzle		Φ=12mm	Φ=10mm	Φ=8mm
Oil recovered C1	Oil (kg)	1.782	1.738	1.694
	Foot (kg)	1.060	1.079	1.097
Oil recovered C2	Oil (kg)	0.865	1.061	1.257
	Foot (kg)	0.566	0.699	0.831
Oil recovered C3	Oil (kg)	0.239	0.200	0.160
	Foot (kg)	0.161	0.139	0.117
Oil recovered C4	Oil (kg)	0.122	0.067	0.012
	Foot (kg)	0.077	0.043	0.009

Figure 4 shows that the nozzle type, respectively the diameter of the exhaust end, affects the inlet flow rate and the specific mechanical energy. The inlet flow rate of the press decrease with the decrease in diameter of the exhaust end, while the specific mechanical energy increases.

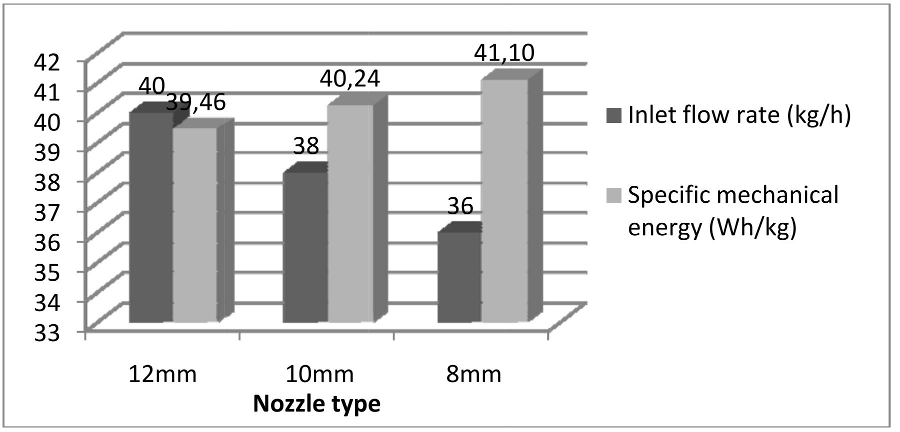

Fig. 4 Variation of inlet flow rate and specific mechanical energy on different nozzle type

In the following figure is presented the influence of nozzle type on the efficiency of extraction process. It can be observed that the utilisation of a nozzle with smaller diameter, which involves a bigger pressure in the pressing chamber, conduces to a better extraction of oil. Using a nozzle with diameter of 8 mm, increased the amount of oil extracted while the amount of press cake decreased compared with the cases of diameter nozzle of 10 or 12 mm.

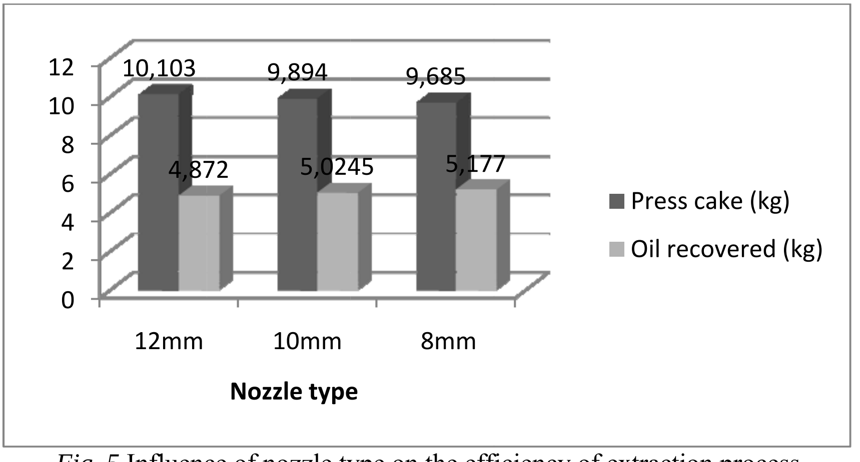

Fig. 5 Influence of nozzle type on the efficiency of extraction process

From the pressing chamber the oil is evacuated through an area provided with holes. This area of 41,8 mm length was divided into 4 equal sections, the oil from each section being collected in one of the tray compartments. The oil distribution along the pressing chamber is presented (for three nozzle types) in the next chart.

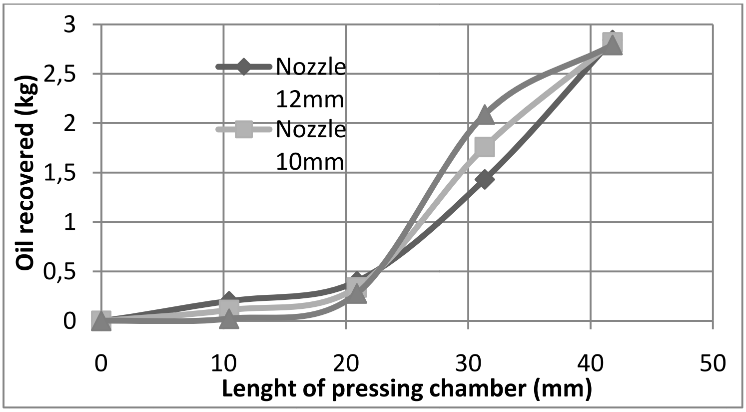

Fig. 6 The oil distribution along the pressing chamber for the three nozzles type

The oil extracted from the sunflower seeds was separated into oil and foot (impurities) through a decantation process. The influence of nozzle dimension, respectively the pressure from the pressing chamber, on oil impurities content was studied. The following figures present the results of decantation process taking into account the tray's compartiments, for all three types of nozzles.

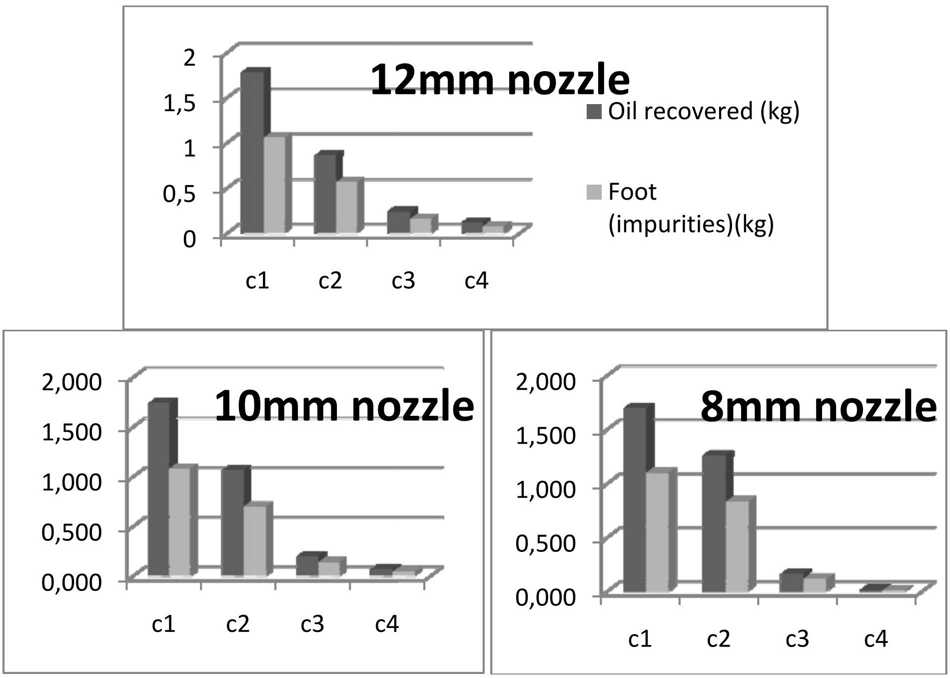

Fig. 7 Nozzle type influence over the impurities content

CONCLUSIONS

The exhaust end diameter has an important influence on the oil extraction yield, the specific mechanical energy and the oil content impurities during the pressing of sunflower seeds.

As it can be seen in figure 4, the inlet flow rate of the press decrease with the decrease in diameter of the exhaust end, while the specific mechanical energy increases.

From the figure 5 it can be observed that using a nozzle with smaller diameter the extraction efficiency will be higher, obtaining a higher quantity of oil and a press cake with less residual oil.

Figure 6, representing the oil distribution along the pressing chamber, shows that the distribution is not uniform. In the first compartment of the collector tray, meaning at the end of the pressing chamber, it was obtained the highest quantity of oil, while in the last compartment (at the beginning of the pressing chamber) the quantity of extracted oil beeing smallest.

As we observed through the experiments, the diameter of nozzle directely affects the impurities/oil proportions. Figure 7 shows that using the 8mm nozzle type for the exhaust end it was obtained an oil with the highest rate of impurities.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Original scientific paper

RESEARCH ON THE WORKING PROCESS AND EFFICIENCY OF A CONICAL SUSPENDED SIEVE WITH PENDULUM MOVEMENT

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SUMMARY

The paper presents the results of some experimental researches on the working process and its efficiency for a sieve having outer conical surface with circular alternate movement, where the angle at cone base is $\alpha = 8^o$. The sieve is suspended at the upper and lower ends by means of three elastic wires (made of silk) with wire diameter ϕ1.5 mm and circular holes diameter ϕ4.2 mm. The sieve is centrally fed at the upper part, through a tube of ϕ25 mm diameter, with adjustable position towards the sieve, in order to obtain various workflows. Separated material is collected under the sieve, in a box having multiple circular concentric segments, of different diameters.

Vibratory movement was obtained using a eccentric drive which acts tangentially to the sieve, in horizontal plane, at adjustable distances. The sieve was used to sort rapeseeds with sizes ranging between ϕ1.6–2.5 mm, in percentage of over 90%. Separation curves are presented in the paper, as well as the distribution of separated material on the generating line of the sieve, the percentage of unseparated seeds at various work capacities and conditions, and also the sorting degree.

***Keywords**: wheat kernels, roller mill, milled wheat, size reduction, size distribution*

INTRODUCTION AND LITERATURE REVIEW

Sieves with oscillatory motion are frequently used for the pre-cleaning of crop seeds, right after harvest, or for their cleaning before placing them on the technological flow of industrial processing.

Most of them have alternative translational oscillatory motion, and are operated with a wide range of drive mechanisms, but, lately, their operation is often performed using moto-vibrators with centrifugal weights.

Separation surfaces of these sieves are generally braids of metallic wires or plastics, as well as perforated sheets with holes, whose geometric features depend on both the seeds form and the size of which separation is performed (width or thickness of the seeds).

For the existence of screening phenomenon, is necessary to have relative motion of the material on the separation surface, which is influenced by the amplitude and frequency of sieve oscillations. Also, the separation process is influenced by other parameters, such as: sieve slope, angles of internal and external friction of the material, size of sieve holes, mean size of the seeds [1,3,4]. Mechanical separation of seeds on sieves with oscillatory motion is not, in fact, a complete separation since the unseparated material will always contain a certain percentage of the seeds or particles of material that should have been separated and which has smaller sizes than the sieve holes, [2]. They have remained in the unseparated material since they haven't meet the conditions required for separation, due tot the too small length of the sieve, or because they did not have enough time to pass through the layer of material underneath them to come in direct contact with the separation surface.

Parameters of oscillatory motion of sieves have a direct influence on the separation of impurities in seed mass, by the movement printed to the material which must move from the supply point to the product take-off area, where particles larger than the sieve holes are collected.

The paper presents the results of experimental researches on the movement of material on a vertical conical sieve made of perforated sheet, having circular alternate motion on the horizontal, and the diameter of circular holes ϕ4.2 mm, which is used for separation of large impurities from rapeseeds.

MATERIALS, METHODS AND PROCEDURES

The conical surface of separation, which was made of perforated sheet with circular holes, had the diameter at cone base ϕ430 mm, for a tilting degree of its generating line towards the horizontal surface of almost 8^o.

Diameter of steel wires, used to suspend the sieve in three equidistant points, both on the upper and lower parts, was ϕ1.5 mm. Drive mechanism of the sieve was designed to ensure mainly a circular alternate motion with a certain amplitude, measured at the edge of conical sieve, on both sides of the neutral position of oscillation in which was set a connection arm of length d (d_{min}, d_{max}) with the drive mechanism (which has straight-line alternate motion on perpendicular direction).

Simplified diagram of the equipment used for the experiments is presented in Figure 1 [6].

Density of circular holes on separation surface was 2.25 holes/cm2, leading to an active surface of about 31%, the length of suspension wires being ll =240 mm, respectively l_2 = 180 mm (see Fig.1).

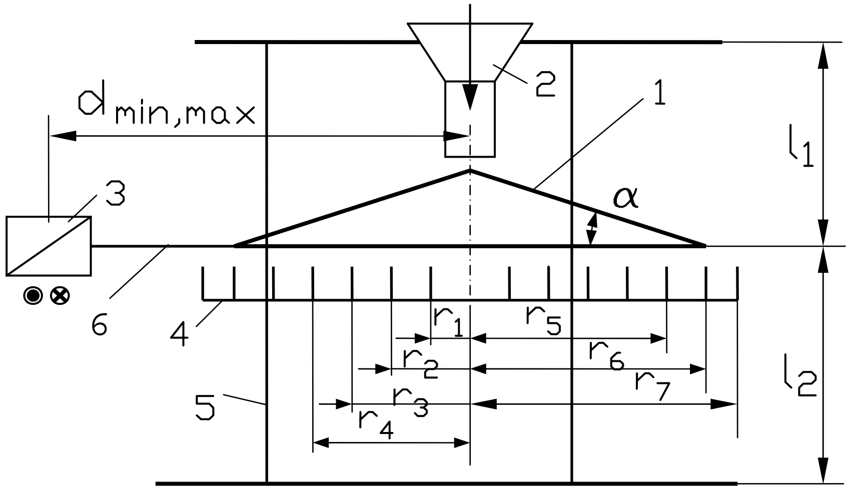

Fig.1 Diagram of conical suspended sieve used for the experiments, 1.conical sieve with ϕ4.2 mm holes; 2.supply hopper adjustable on height; 3.drive mechanism with oscillating crank lever; 4.collector box; 5.elastic steel wires; 6.connection lever (arm)

By the eccentric, tangential arrangement of the arm joint of drive mechanism to the conical sieve (see Fig.2), it develops almost circular oscillations towards the vertical axis of the cone, the motion being assumed oscillatory, since the vertical axis of the sieve (its center) was not set to move in the direction of arm 6 jointed with the sieve (placed radially at the base circle of the cone).

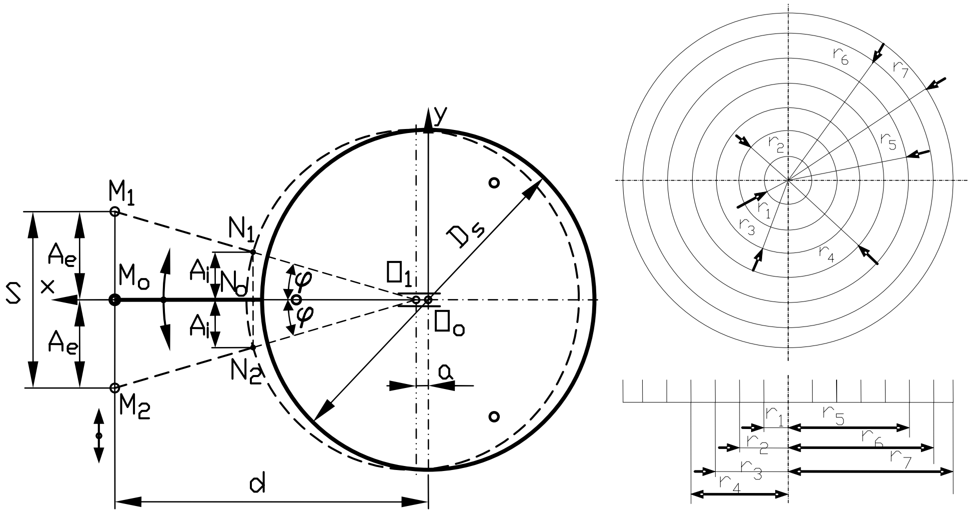

Fig.2 Diagram for the calculus of oscillation amplitudes of the sieve and the collector box under the sieve

Oscillation frequency could be changed from the electric motor drive, being used its values of 250, 520 and 790 osc/min, while the oscillation amplitude was modified by changing the arrangement position of drive mechanism in relation to the radial arm of the sieve, namely by modifying distance d (fig.2) to values 480, 460, 440 respectively 420 mm, thus obtaining amplitudes of 3.58; 3.74; 3.91 and 4.10 mm.

Reduced dimensions of separation surface were chosen so that the experimental tests do not require large amounts of material, but by geometric similarity its dimensions can be modified, so that the work capacity of the sieve in operation conditions can be increased.

The equipment designed and experimentally developed within paper [6] was used to estimate the movement of material on the sieve, and the efficiency of rapeseeds separation and sorting process.

The stroke of drive mechanism, on perpendicular direction on arm 6 (Fig.1), in horizontal plane, was 16 mm, thus its angle, in extreme positions was about 1^o ($\pm 0.05^o$), for all four positions of the drive mechanism.

The motion of sieve along the connection arm (on Ox axis, Fig.2) was very small (about 0.07 mm), thus it can be assumed a alternate circular motion of the sieve, regardless of the point in which the drive mechanism and the connection arm are jointed (distance d is variable).

For sieve supply was used a supply hopper fitted with an outlet diameter ϕ25 mm, above the sieve, on its vertical axis, with the possibility to adjust the height of the hopper, in order to modify the circular flow section between the sieve and the lower edge of the outlet hole. To collect the material separated through sieve holes, was designed an circular collector box with multiple circular concentric sections having various radius towards the sieve axis, placed right under the sieve, also being suspended on the three metallic wires used to suspend the sieve.

The collector box has following collecting diameters: 80, 140; 200, 260, 320, 410 respectively 460 mm. Rapeseeds used for the experiments were harvested from Southern Romania and stored for approximately 6 months. Mass of each material sample was always the same, consisting of 0.5 kg of seeds, in addition to 15 grams (3%) of large foreign bodies consisting of parts of rapeseed stalks with sizes between 3 and 4 mm.

Rapeseed moisture was 7.65-8.05%, and straw moisture was 8.35-8.70%, both determined using a Partner MAC 110 thermobalance, for a drying temperature of 105^oC. Seed sizes were between ϕ1.5-2.5 mm (over 90%), determined by sieving on sieves having the side of holes of 150 μm, respectively 250 μm.

For three adjusted distances of the supply hopper towards the sieve, the values of feed flow were: 0.020 kg/s, 0.033 kg/s and 0.042 kg/s.

After performing the experimental tests, the material from each compartment of the collector box was collected, weighted and recorded in data tables, correlated with the position of the compartment on the sieves generating line. The feed flow was calculated as a ratio between the sample mass and the time needed for the material to flow from the hopper.

It was noticed that straw impurities from the mass of seeds have totally passed over the lower edge of the sieve, for all the tests performed.

To ease data processing and to plot the experimental curves representing the working process, the mass of material collected in each of the boxes under the sieve has been reported to the seeds mass of the sample, the results being presented as a percentage of it.

Based on the percentage of separated seeds at different collection radius of the sieve were plotted curves of separation intensity, namely the relative distribution of the separated material on the radius of base circle of the sieves cone, as well as the curves of cumulative separation, representative for the separation of granular materials on the sieves.

Computed regression analysis of the experimental data were performed using Microcal Origin 6.0, those data being obtained for pre-established work conditions, with the normal distribution function (distribution law frequently used in such analysis), for which were also determined the correlation coefficients, χ^2 and R^2 (Eq. 1) [7,8]:

$$p_x(\%) = a \cdot e^{-b(x-c)^2} \tag{1}$$

where: $p_x(\%)$ is the proportion of material separated on a lenght (radius) interval of the sieve; a, b, c – regression coefficients depending on the work regime parameters and on the physical characteristics of the processed material.

Thus, in equation (1) ‚a' is the maximum percentage of material collected in the boxes under the sieve, coefficient ‚b' gives data on the dispersion towards the maximum position, while ‚c' is the sieve radius related to the maximum percentage of separated seeds (or the mean in the function of normal distribution).

RESULTS AND DISCUSSION

Experimental results for feed flow 0.033 kg/s, for the four oscillation amplitudes of the sieve and three oscillation frequencies are presented in Table 1.

Based on data presented in Table 1, distribution curves were plotted for the material separated on the radius of collector box, respectively regression analysis was performed for these data with the proposed function (Eq.1) and the obtained graphics are presented in Fig.3. Values of the coefficients of regression equation, a, b and c, for the proposed function and the work regimes mentioned in Table 1, and the values of correlation coefficients χ^2 and R^2 are presented in Table 2.

Analysis of data in Table 2 and of the curves in Fig.3 showed a good correlation of the experimental results (weights of the amounts of material collected under the sieve on its horizontal radius in percentage) with the regression function (Eq.1), for which the correlation coefficient R^2 had very good values ($R^2 \geq 0.960$), in most of the analyzed cases.

Influence of the oscillation frequency of the sieve on the separation process and ultimately on the losses of seeds that reach and pass beyond the lower edge of the sieve could be estimated by the maximum (peak) position of separation curves towards the top of the sieve (where the material is supplied) is presented in Fig.3, also depending on the value of oscillation amplitudes, as shown by data in Table 1.

Table 1 Variation of the amount of material collected under the sieve (%), for feed flow Q_2=0.033 kg/s and four sieve oscillation amplitudes, at different oscillation frequencies

No.	M_s= 500 g		Sieve radius from which seeds are collected x, (m)								
	Amplitude	Frequency	Separated seeds	0	0.04	0.07	0.1	0.13	0.16	0.205	After sieve
1	A_1=3.58 mm	250 osc/min	g	0	153	184	109	38	11	5	0
			%	0	30.6	36.8	21.8	7.6	2.2	1	0
2		520 osc/min	g	0	104	131	108	99	56	2	0
			%	0	20.8	26.2	21.6	19.8	11.2	0.4	0
3		790 osc/min	g	0	164	178	149	9	0	0	0
			%	0	32.8	35.6	29.8	1.8	0	0	0
4	A_2= 3.74 mm	250 osc/min	g	0	141	159	105	52	28	15	0
			%	0	28.2	31.8	21	10.4	5.6	3	0
5		520 osc/min	g	0	133	157	88	55	30	17	20
			%	0	26.6	31.4	17.6	11	6	3.4	4
6		790 osc/min	g	0	158	178	116	48	0	0	0
			%	0	31.6	35.6	23.2	9.6	0	0	0
7	A_3= 3.91 mm	250 osc/min	g	0	127	138	107	56	53	19	0
			%	0	25.4	27.6	21.4	11.2	10.6	3.8	0
8		520 osc/min	g	0	136	162	91	57	25	13	16
			%	0	27.2	32.4	18.2	11.4	5	2.6	3.2
9		790 osc/min	g	0	151	181	102	49	16	1	0
			%	0	31.6	35.6	23.2	9.6	0	0	0
10	A_4= 4.10 mm	250 osc/min	g	0	116	128	109	63	59	24	1
			%	0	23.2	25.6	21.8	12.6	11.8	4.8	0.2
11		520 osc/min	g	0	140	183	95	60	20	2	0
			%	0	28	36.6	19	12	4	0.4	0
12		790 osc/min	g	0	146	186	90	51	22	5	0
			%	0	29,2	37,2	18	10,2	4,4	1	0

For feed flow Q_2 = 0.033 kg/s and sieve oscillation amplitude A_1= 3.58 mm, it can be noticed that with the increase of frequency f_1 = 250 osc/min to f_2 = 520 osc/min, the peak position of the distribution curve of the separated material on the sieve generating line (given by the value of coefficient ‚c' in Eq.1) moves on the radius (generating line) of the sieve from its inner to outer part (from feed to outlet), from c = 0.066 m to c= 0.087 m, and then reaching again the feed point (c= 0.067 m) at frequency f_3 = 790 osc/min, thus being observed that the separation process is irregular.

Modifying the oscillation amplitude from A_1 = 3.58 mm to A_2 = 3.74 mm leads to an improvement of the separation process, with the increase of the oscillation frequency of the sieve, given by the peak position of the distribution curve of the separated material on the sieve generating line, which moves from the outlet towards the center of the sieve (from outlet towards feed), from c = 0.069 m for oscillation frequency f_1 = 250 osc/min, to c= 0.059 m, for frequency f_2 = 520 osc/min, respectively to 0.056 m for oscillation frequency f_3 = 790 osc/min.

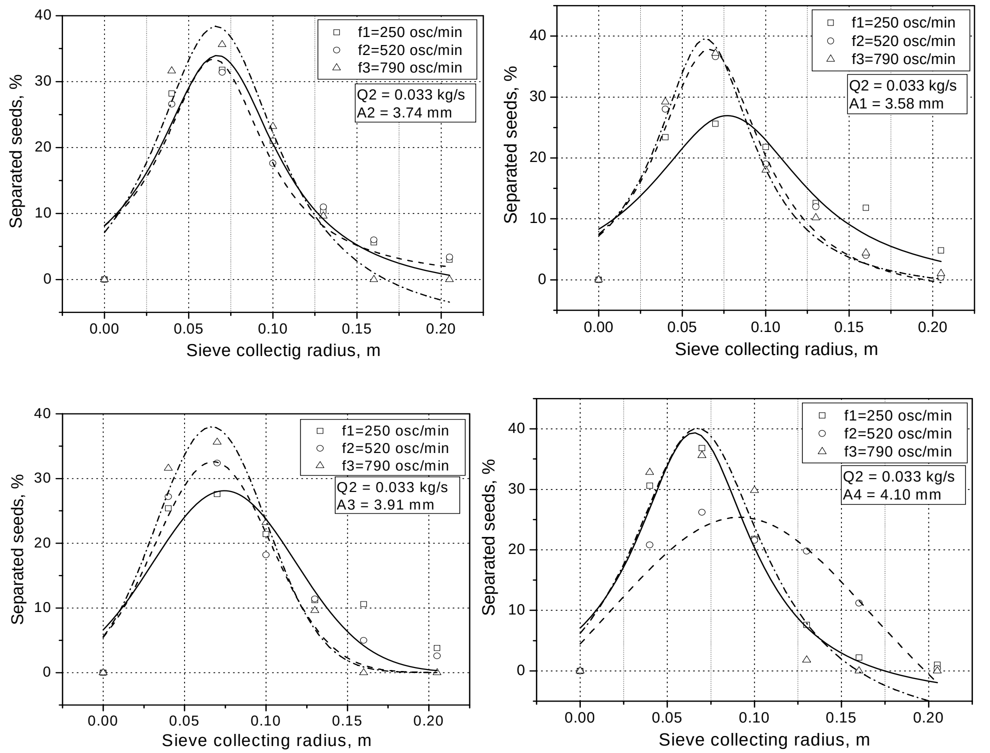

Fig.3 Influence of oscillation frequency of sieve on the separation process of seeds on the generating line of conical sieve, for feed flow Q_2 = 0.033 kg/s and four oscillation amplitudes

Table 2 Coefficients of regression equation (Eq. 1), a, b and c, respectively correlation coefficients χ^2 and R^2 with experimental data, for feed flow Q_2 = 0.033kg/s

No sample	Work regime parameters	Normal function (Eq.1)	a	b	c	χ^2	R^2
1	A_1 = 3.58 mm	f_1 = 250 osc/min	38.619	481.165	0.066	10.231	0.971
2		f_2 = 520 osc/min	26.510	200.021	0.087	18.428	0.891
3		f_3 = 790 osc/min	40.584	469.899	0.067	28.419	0.937
4	A_2 = 3.74 mm	f_1 = 250 osc/min	33.076	372.561	0.068	20.901	0.914
5		f_2 = 520 osc/min	31.558	384.544	0.067	25.297	0.882
6		f_3 = 790 osc/min	38.004	433.279	0.066	14.615	0.960
7	A_3 = 3.91 mm	f_1 = 250 osc/min	28.115	260.803	0.074	31.852	0.815
8		f_2 = 520 osc/min	32.617	392.096	0.068	22.586	0.904
9		f_3 = 790 osc/min	38.007	433.363	0.067	14.616	0.962
10	A_4 = 4.10 mm	f_1 = 250 osc/min	25.760	207.517	0.080	29.794	0.800
11		f_2 = 520 osc/min	36.159	437.265	0.067	20.679	0.932
12		f_3 = 790 osc/min	37.622	495.839	0.065	19.482	0.937

The same phenomenon presents the movement of the material on the sieve for amplitude A_3, respectively it shows a small improvement in the movement of material on the sieve with the increase of oscillation frequency, which leads to the assumption that the speed of material on the sieve increases, but, although the maximum percentage of separated seeds on the generating line of the sieve is closer to the sieves top, a lot of seeds will separate later, so the dispersion (scattering on the sieve) is larger.

Thus, the movement of peak point from the separation curve (c) with oscillation frequency, for the four oscillation amplitudes, at feed flow $Q_2 \approx 0{,}033$ kg/s is shown in Figure 4.

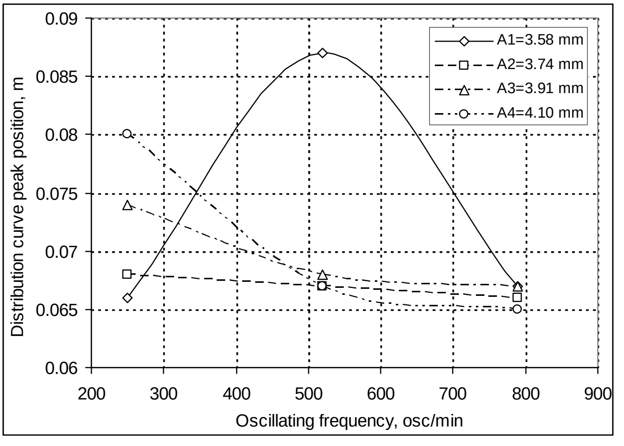

Fig.4 Peak position of the separation curve (c) at different sieve frequencies and amplitudes, for feed flow $Q_2 \approx 0.033$kg/s

It can be stated that for feed flow $Q_2 = 0.033$ kg/s, for the oscillation frequencies used in the experiments, optimal amplitude of oscillation is $A_1 = 3.58$ mm, for which it was found a good correlation between the results and the normal regression function (Eq.1) and for which the correlation coefficient R^2 had satisfactory values ($R^2 \geq 0{,}891$).

Still, regardless the amplitude, for oscillation frequency of 790 osc/min, the amount of separated seeds towards the lower part of the sieve decreased significantly compared to other cases, so it can be assumed that the separation rate increases with the oscillation frequency, but there must be a correlation between the hole diameter and the passage time of the seeds through the holes, because with the increase of oscillation frequency, the passage time of the seeds through the holes decreases.

On the degree of sorting obtained with conical sieves, the literature specifies that a sieve with oscillatory motion, no matter the shape of its holes, it can be used with good results for dimensional sorting of seeds from the same crop or for a granular material of the same composition.

For a very thin layer of material with particles which do not interact with each other, the first area of the sieve separates the smaller seeds, while at greater distances from the supply area are separated the seeds with increasing sizes. For higher thickness of the layer of material, the oscillation motion of the sieve creates favourable conditions for material arrangement in layers, especially when from bottom to top circulate a low speed airflow. Thus, higher mass and better developed seeds will be in contact with the sieve, while in lower layers are found increasingly smaller, less developed and low weight seeds.

Thus, seeds that are in contact with the sieve will have a higher probability to pass through the holes than the seeds from upper layers, which do not meet all the conditions of passage through sieve holes, especially since they must also pass through the general layer of material.

However, since the supply until the material gets to arrange in layers, more or less time can pass depending on operating mode parameters, so that separation will be random on the first work area of the sieve, depending on how the general layer of material reaches on the sieve.

Tests were performed on the sorting degree of conical sieve, for the experimental equipment presented in Fig.1, resulting in size distribution of seeds collected in each circular compartment of the collector box under the sieve.

Calibration was done by sieving the collected seeds using sieves with various hole sizes: 1.25 mm, 1.6 mm, 2 mm and 2.5 mm. Experiments were performed for feed flow Q_2 = 0.033 kg/s and oscillation amplitude A_1 =3.58 mm, for all three oscillation frequencies used in previous experiments.

For a better analysis of sorting phenomenon, were plotted the regression curves of experimental data with the normal distribution function (Eq.1), for all analyzed cases, and their diagrams are shown in Fig.5 for three of four fractions of different sizes of seed mass, including the initial mixture of seeds (d > 2 mm, d = 1.6 – 2 mm, d = 1.25 – 1.6 mm, d < 1.25) depending on the oscillation frequency (f_1 = 250 osc/min, f_2 = 520 osc/min, f_3 = 790 osc/min).

The analysis of diagrams shows about the same rate of distribution curves for each of the four fractions with the one corresponding to the general seeds mixture, so that at higher oscillations the separation occurs quickly, while for oscillation frequency f_1 = 250 osc/min (low frequency) all four fractions are separated later.

However, a better size sorting requires lower frequency, as it can be observed from the diagrams, at which the peak position of distribution curve increases with the decrease of seed dimensions (as specified by literature), especially for seeds smaller than 2 mm.

An increase of peak position of distribution curves is recorded at frequency f_2 = 520 osc/min, for all four sorting fractions of the general mixture, but a little different situation is recorded at frequency f_3 = 790 osc/min, where the trend is to reduce the peak position of distribution curve for seeds with sizes becoming smaller, which means that a greater agitation of the material on the sieve creates better conditions for small seeds passing through the layer of seeds and their easier and faster separation.

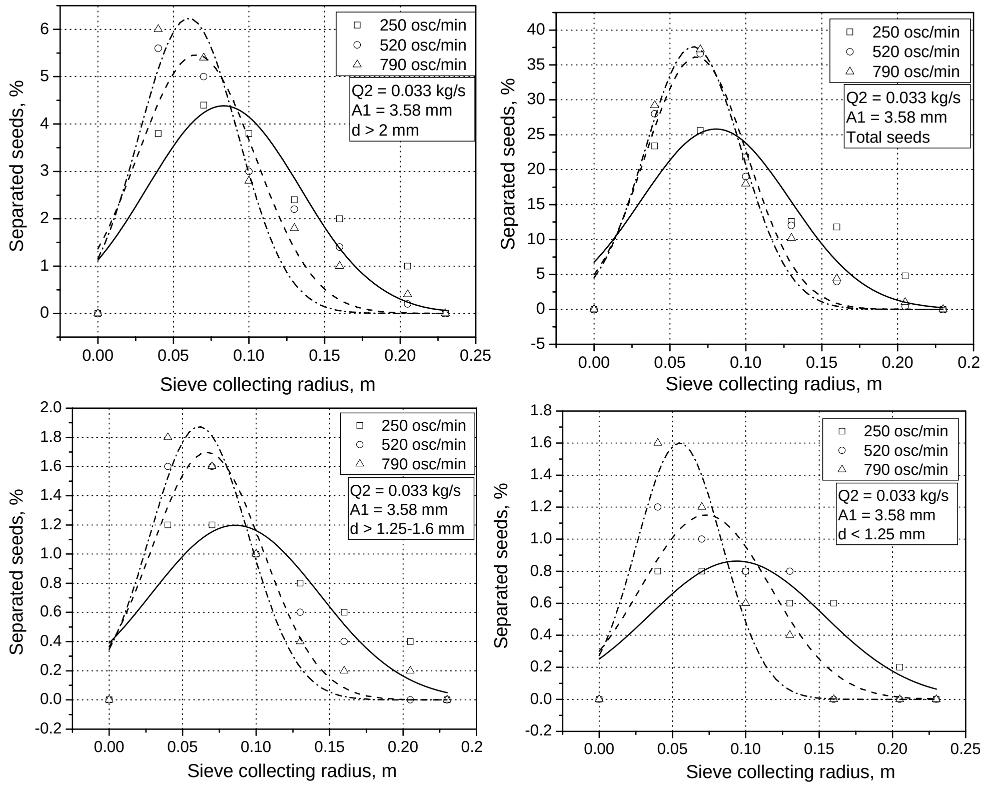

Fig.5 Distribution curves on sieve collecting radius for fractions of seed mixture separated by oscillant conical sieve

CONCLUSIONS

To analyze the separation process on a conical sieve with outer profile was conceived, designed and built experimental equipment with oscillating crank lever for driving the sieve in plane circular oscillation motion.

Analysis of the influence of sieves kinematical parameters on the separation process was estimated by peak position of distribution curves (normal type), for the material that has passed through the sieve holes and was collected under the sieve, at various distances from sieve upper part, where feeding was done.

It was found that the normal distribution function correlates well the experimental data, the correlation coefficient R^2 having in all analysed cases, values over 0.960. Peak position of distribution curve modifies with the change of oscillations amplitude, lower amplitude and higher oscillation frequency leading, generally, to a faster separation of the material through the holes of the sieve.

An effective separation of seeds through sieve holes occurs at a frequency of oscillation ranging between 250 – 520 osc/min and mean amplitudes of sieve displacement on the direction of drive arm (considered on tangential direction to base circle of the sieve).

Sieve can be successfully used for size sorting of seeds from the same crop, if the operating regime parameters are chosen properly.

From observations made after performing the experimental tests it was found that there is a better sieving in the opposite drive area, where these values are much lower in amplitude, compared to the ones in the drive area. This leads to higher speeds of the sieve that exceed the technological speed limit for sieving. To avoid inefficient screening areas, restrictions must be introduced on sieve binding or a symmetric drive.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

BIOMASA ZA GORIVO I STROJ ZA UBIRANJE I BALIRANJE

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SAŽETAK

Biomasa u proizvodnji energije iz obnovljivih izvora je u EU zastupljena s 2/3 udjela. Proizvodnja biogoriva prve generacije utječe na cijene pojedinih sirovina kao što su kukuruz, soja i šećerna trska, ali zasada ne značajno na ukupni porast cijene hrane. Rješenje pružaju biogoriva druge generacije koja imaju širi izbor sirovina koje nisu ljudska hrana, no njihov razvoj je sporiji od očekivanog. Proizvodnju biomase bi trebalo čim više osnivati na površinama koje nisu konkurencija uzgoju tradicionalnih kultura i ne stvarati nove obradive površine krčenjem šuma. Za ubiranje samonikle biomase kao i uzgojenih energetskih kultura može se koristiti stroj Biobaler WB55 koji u jednom prohodu ubire i balira biomasu. Može raditi u nasadima energetskih kultura, u voćnjacima, na zapuštenim poljoprivrednim površinama, na zelenim površina ispod el. vodova i uz ceste. Učinak stroja može biti do 40 bala h^{-1} u nasadima brzorastućeg drveća u sječi vrba, i 15-18 bala h^{-1} u prirodnim uvjetima u ubiranju niskog šumskog raslinja.

Ključne riječi: *biomasa, biogoriva, etanol, stroj za ubiranje i baliranje biomase*

UVOD

Obnovljivi izvori energije imaju veliki prirodni potencijal i predstavljaju novo gospodarsko polje koje ostvaruje visoke stope rasta. Od 2006. do 2008. godine ulaganja u obnovljive izvore energije su se udvostručila diljem svijeta sa 63 na 120 milijardi američkih dolara, u Njemačkoj je u 2009. godini udio obnovljivih izvora energije iznosio 10% od ukupne energetske potrošnje (Scherr, 2010). Ulazimo u razdoblje u kojem će rasti udio obnovljivih izvora u opskrbi energijom, dok će se udio konvencionalnih izvora energije smanjivati.

Raznolikost obnovljivih izvora energije je sve veća i proizvodnja „zelene" električne struje kao alternativne izvore energije koristi snagu vjetra, biomasu i sunčevo zračenje.

Razvijaju se i rješenja za smanjenje onečišćenja okoliša u elektranama koja koriste konvencionalne izvore energije. Europska komisija je predvidjela veliku financijsku podršku za tehnologiju CCS elektrana na ugljen (*Carbon Capture and Storage*) gdje se ugljikov dioksid (CO_2) izdvaja i skladišti u podzemne spremnike.

Primjena biogoriva odnosno biomase u proizvodnji obnovljivih izvora energije imati će utjecaj na razvoj poljoprivrede, razvoj ruralnih regija, korištenje zemljišta, razvoj gospodarstva i zaposlenost. U Europi je korištenje biomase u proizvodnji obnovljivih izvora energije zastupljeno s 2/3 udjela i značajno će doprinijeti postizanju zacrtanog plana po kojem bi do 2020. godine od ukupne potrošnje energije 20% bilo dobiveno iz obnovljivih izvora energije (Rechberger et al., 2009). Prognoza je da će u ukupnoj proizvodnji bioenergije bioplin biti zastupljen barem s 25% te dobiven od životinjskih izlučevina, silaže cijele biljke i raznih organskih otpada (Holm Nielsen i Oleskowicz-Popiel, 2008).

UTJECAJ BIOGORIVA NA CIJENU HRANE

Na rast cijena žitarica utjecala je povećana proizvodnja biogoriva prve generacije kao što su etanol i biodizel. Mnogi faktori utječu na cijenu hrane kao što su: vremenski uvjeti, cijena nafte, razvoj gospodarstva, nizak stupanj ulaganja u istraživanja u poljoprivredi, politika uvoza i izvoza, spekulativna ulaganja, korištenje obradivog zemljišta i potražnja za njime (urbanizacija, pošumljavanje i dr.). Studije ukazuju da su biogoriva utjecala na globalnu krizu u proizvodnji hrane od 2007. do 2008. godine i razlikuju se u pretpostavkama dugoročnog utjecaja proizvodnje biogoriva na cijene i opskrbu hranom (Timilina i Shrestha, 2010). Baier et al. (2009) procjenjuju da je povećana proizvodnja biogoriva od 2006. do 2008. godine utjecala na porast cijene kukuruza i soje, uglavnom zbog proizvodnje biogoriva u SAD-u. Proizvodnja biogoriva u EU je utjecala malim dijelom na povećanje cijene ječma, kukuruza i soje, dok je veliki utjecaj na povećanje cijene šećera imala proizvodnja etanola u Brazilu (Timilina i Shrestha, 2010). U Europi je 2008. godine oko 5 milijuna tona zrna žitarica korišteno za proizvodnju etanola, a zbog vremenskih uvjeta ukupni prinos može varirati i do 50 milijuna tona (Rechberger et al., 2009). Proizvodnja biogoriva utječe na cijene pojedinih sirovina, ali zasada ne značajno na ukupni porast cijene hrane. Utjecaj povećane proizvodnje biogoriva od 2006. do 2008. godine je iznosio 12% na rast indeksa cijena hrane prema IMF-u, a od navedenih 12% oko 60% otpada na SAD, oko 15% na EU i oko 14% na Brazil (Baier et al., 2009.). Udio ostalih faktora na ukupno povećanje cijene hrane je iznosio 88%. Pretpostavka je da će se potražnja za poljoprivrednim proizvodima udvostručiti do 2050. godine, s godišnjim rastom od najmanje 1.7% (Qaim i Saenger, 2010).

Ukupna proizvodnja etanola u svijetu je višestruko veća od proizvodnje biodizela, pogotovo u SAD-u i Brazilu. U 2008. godini ukupna proizvodnja etanola u svijetu je bila 67 milijardi litara (ne uključujući ETBE, smjesu etanola i isobutilena korištenu kao mješavinu s benzinom), dok je za biodizel iznosila 14.7 milijardi litara (Timilina i Shrestha, 2010). Europske zemlje izuzev Švedske i Španjolske imaju veću proizvodnju biodizela od etanola. Godišnja proizvodnja etanola je dosegla oko 98 milijardi litara (Bickret, 2010) i najvećim dijelom se koristi kukuruz kao sirovina. Glavne sirovine u proizvodnji etanola su kukuruz i šećerna trska, a u manjoj mjeri šećerna repa, pšenica, ječam i raž, a u proizvodnji biodizela su uljana repica i soja.

Za proizvodnju energetskih kultura u EU-27 moglo bi se koristiti od 10 do 30% obradivih površina (Holm Nielsen i Oleskowicz-Popiel, 2008). Države koje imaju veći udio poljoprivrednog zemljišta po glavi stanovnika imaju dobar potencijal za proizvodnju biomase namijenjene proizvodnji energije, u EU-27 to iznosi 0.41 ha po glavi stanovnika, a u Hrvatskoj 0.67 ha. U pogledu klimatskih promjena smatra se da biogoriva doprinose smanjenju stakleničkih plinova ako njihovom proizvodnjom nije došlo do prenamjene zemljišta. Ako je proizvodnja biomase postignuta pretvorbom šumskog zemljišta bogatog ugljikom u obradivu površinu tek nakon nekoliko godina će se postići doprinos smanjenju stakleničkih plinova.

Proizvodnja biogoriva sa sirovinama koje se koriste i u ljudskoj prehrani utječe na cijenu hrane. Prisutan je stav koji ne podržava proizvodnju biogoriva iz biomase koja je ljudska hrana, osim u državama koje imaju viška zemljišta i jako razvijenu industriju biogoriva. Rješenje pružaju biogoriva druge generacije koja kao sirovinu koriste lignocelulozni materijal, no u njihovom razvoju su prisutne određene tehničke i gospodarske zapreke.

RAZVOJ BIOGORIVA DRUGE GENERACIJE

Ograničene mogućnosti biogoriva prve generacije u zamjeni za fosilna goriva i u smanjenju stakleničkih plinova potiču razvoj biogoriva druge generacije, uz pretpostavku da će se u proizvodnji energetskih kultura koristiti poljoprivredne površine čija će eksploatacija imati manji utjecaj na cijenu hrane, kao i tla slabije kvalitete uz visoke prinose biomase primjenom biotehnologije (Carriquiry et al., 2010).

Nakon uspješnog razvoja biogoriva prve generacije, očekivao se brži razvoj biogoriva druge generacije kao što su bioplin, BtL (Biomass to Liquid) i celulozni etanol za čiju je proizvodnju veći izbor sirovina koje nisu ljudska hrana. Ukupno je šest pokusnih postrojenja u EU za proizvodnju celuloznog etanola ili BtL-a, najveći proizvodni pogon je u Njemačkoj u Choren-u Saxony, godišnjeg kapaciteta od 18 milijuna litara Btl-a, kao sirovina se koristi biomasa brzorastućeg drveća (Langbehn, 2011). Razvoj biogoriva druge generacije u SAD-u je velikim dijelom usmjeren na proizvodnju celuloznog etanola kao zamjene za etanol koji se koristi kao dodatak motornim gorivima.

Gospodarski potencijali biogoriva druge generacije ovise o površini zemljišta koja je potrebno za uzgoj sirovina s obzirom na njihov prinos i o troškovima proizvodnje biogoriva (Carriquiry et al., 2010). Potencijalne sirovine za proizvodnju biogoriva druge generacije su energetske kulture koje nisu namijenjene ljudskoj prehrani, nusproizvodi iz poljoprivrede i šumarstva, jatropha i alge. U proizvodnji biogoriva prve generacije preko 65% od ukupnih troškova proizvodnje otpada na sirovine, dok kod biogoriva druge generacije to iznosi od 30 do 50% (Carriquiry et al., 2010). Unatoč jeftinijoj sirovini troškovi proizvodnje biogoriva na bazi celuloze su viši u odnosu na proizvodnju etanola iz kukuruza jer se koriste skuplji industrijski enzimi i veća su kapitalna ulaganja (Coyle, 2010). Biomasa energetskih kultura i nusproizvoda je voluminozna te je zahtjevnije organizirati njeno ubiranje, transport i skladištenje, a također na cijenu sirovina može utjecati kratko razdoblje podesno za berbu i varijabilnost prinosa, kao i udaljenost biorafinerija koje radi kontinuiranog procesa proizvodnje moraju imati osiguran stalni priliv sirovina. Na cijenu sirovine utječe i kalkulacija proizvođača kolika je dobit u proizvodnji energetskih kultura u odnosu na drugi način korištenja istog zemljišta.

Proizvodnju celuloznog etanola bi potaknulo miješanje veće količine etanola s benzinom. U Njemačkoj, europska norma DIN EN 228 omogućuje upotrebu mješavine goriva sa sadržajem etanola do 5% (E5), u svijetu ovisno o državi dopušteno je miješanje od 3% do 24 %. Veći broj motornih vozila koja su prilagođena za korištenje različitih goriva (flexible fuel vehicles - FFV) koja mogu koristiti E85 gorivo, kao i veći broj benzinskih postaja koje toče etanol također bi pogodovali isplativijoj proizvodnji celuloznog etanola.

Tvrtke koje su uključene u proizvodnju biogoriva druge generacije većinom kao sirovinu koriste biomasu iz poljoprivrede. Planirano je da se za sirovine koriste nusproizvodi kao što je slama, zatim trave i sl. Glavna prednost korištenja slame i kukuruzovine je što za njihovu proizvodnju nisu potrebne dodatne obradive površine, i samim time imaju manji utjecaj na cijenu hrane. Skupljanje biljnih ostataka s polja može pozitivno utjecati na neke usjeve u kontroli bolesti i štetnika, kao i na povećanje temperature tla u proljeće tijekom klijanja (Andrews, 2006). Intenzivno skupljanje biljnih ostataka s površine tla može imati i štetan utjecaj na prinos, svojstva tla i okoliš, jer su važni za tlo radi očuvanju njegovih svojstva, vlažnosti, povećanja plodnosti i obogaćivanja ugljikom (Blanco-Canqui i Lal, 2009).

Višegodišnje krmne kulture mogu biti značajna sirovina za biogoriva druge generacije. Trava je prikladna biomasa za proizvodnju celuloznog etanola, divlji proso (*Panicum virgatum* L.) se često navodi zbog manjih potreba za vodom i hranjivima, pozitivnog utjecaja na okoliš i prilagodljivosti na manje plodna tla (Keshwani i Cheng, 2009). Kvalitetna krmiva koja imaju potencijal kao energetske kulture za biogoriva druge generacije su lucerna (*Medicago sativa* L.) i blještac (*Phalaris arundinacea* L.). Mischantus (*Mischantus x giganteus* Greef et Deu.) je pogodan kao energetska kultura zbog tolerancije na hladnoću i manjih potreba za dušikom. Od brzorastućeg drveća pogodne su vrba (*Salix* L.) i topola (*Populus* L.), kulture kratke ophodnje – KKO.

Navedene energetske kulture imaju određene prednosti u odnosu na druge sirovine, manji su troškovi proizvodnje, sprječavaju eroziju tla i poboljšavaju njegova svojstva. S većim prinosom biomase može se dobiti veća količina energije po jedinici površine. U bliskoj budućnosti cilj je postići prosječni prinos biomase od oko 20 t ST/ha (Holm Nielsen i Oleskowicz-Popiel 2008). Usprkos visokim prinosima energetskih kultura u biomasi činjenica je da su za njihovu proizvodnju potrebne poljoprivredne površine. Proizvodnju energetskih kultura bi trebalo čim više organizirati na površinama na kojima se ne proizvodi hrana i ne koriste se za ispašu kako bi se umanjio njen utjecaj na cijenu hrane. Zemljišta na kojima se uzgajaju ili se planiraju uzgajati poljoprivredne kulture, na kojima je predviđena izgradnja i infrastruktura, kao i šume trebale bi biti izuzeta od proizvodnje energetskih kultura.

STROJ ZA UBIRANJE I BALIRANJE BIOMASE

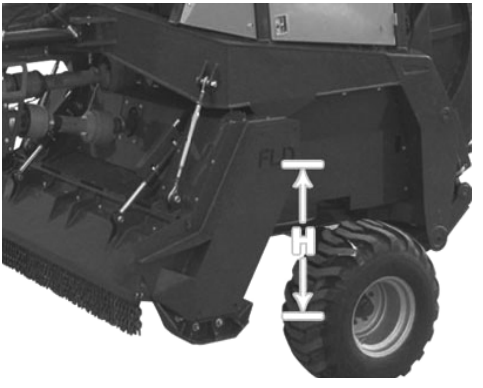
Ubiranje odnosno sječu i baliranje biomase u jednom prohodu obavlja stroj sličan preši za velike valjkaste bale. Balira različite vrste bilja, grmlja i drvenastih kultura čiji je promjer sječe do 15 cm. Ubire se biomasa sa zelenih površina ispod el. vodova, uz ceste, sa zapuštenih poljoprivrednih površina, u nasadima brzorastućih energetskih kultura, u voćnjacima i dr. U berbi vrba se inače koriste krmni kombajni s posebnim hederom koji ima sustav za sječu s jednom ili dvije kružne pile. Uzgoj brzorastućeg drveća na kultiviranom tlu je sličniji uzgoju poljoprivrednih kultura nego klasičnom šumarstvu, te se primjenjuje i na poljoprivrednom zemljištu (Christhersson i Senneby-Forsse, 1994).

Sl. 1 Stroj BioBaler WB 55 proizvođača Anderson Group co. u berbi-sječi vrbe
Fig. 1 Anderson Group co. BioBaler WB 55 harvest biomass in short rotation crop of willow

Canto et al. (2011) su provodili ispitivanje dva različita sustava ubiranja i baliranja šumskog niskog raslinja - grmlja i mladica. Biomasa grmlja je iznosila od 16.23 do 23.07 t ha^{-1}, a mladica od 0.00 do 1.37 t ha^{-1}. Prvi sustav je bio prototip stroja za ubiranje i baliranje biomase u jednom prohodu radnog zahvata od 230 cm (Lavoie, 2008), odnosno modificirana preša za valjkaste bale New-Holland BR740 razvijena u suradnji Agriculture and Agri-Food Canada sa Sveučilištem Laval u Québec-u, u Kanadi i traktor Caterpillar Challenger MT565B snage motora od 108 kW. U drugom sustavu su operacije ubiranja i baliranja bile odvojene i obavljene u dva prohoda. U prvom prohodu je ubiranje izvedeno malčerom BH-74 SS Fecon, radnog zahvata od 152 cm s traktorom gusjeničarom Supertrak SK 140 TR snage motora od 104 kW, a druga varijanta je bila malčer BH-120 SS Fecon, radnog zahvata od 216 cm s traktorom gusjeničarom Supertrak SK 300 TR snage motora od 224 kW. U drugom prohodu baliranje je izvedeno s prešom za valjkaste bale Claas Rollant 250 i traktorom Caterpillar Challenger MT545B snage motora od 89 kW. Prema rezultatima ispitivanja sustav ubiranja i baliranja u jednom prohodu ima niži utrošak goriva po toni balirane biomase i iznosi 6.23 l t^{-1}, no ubrana je manja količina biomase po jedinici površine, dok je kod drugog sustava utrošak goriva po toni balirane biomase iznosio 7.15 l t^{-1} i u drugoj varijanti 9.03 l t^{-1} (Canto et al., 2011).

Studenti koji su sudjelovali u adaptaciji New-Holland BR740 preše razvili su stroj iste namjene FLD WB55 Woody Baler kojeg danas proizvodi Anderson Group co. U ispitivanjima pri ubiranju niske šumske vegetacije na plantaži bora WB55 je vukao i pogonio traktor Fendt 818 (136 kW). Izmjerene su slijedeće prosječne vrijednosti: vrijeme potrebno za ubiranje biomase, formiranje i istovar bale je iznosilo 4.3 minute, masa bale je iznosila 450 kg i udaljenost između bala 229 m, učinak je bio 14.7 bala h^{-1}, odnosno 0.81 ha h^{-1} pri radnoj brzini od 4.18 km h^{-1} (Klepac i Rummer, 2010). Ako bi se niska šumska vegetacija sa iste površine ubirala svake treće godine nakon pomlađivanja (regeneracije) njena biomasa bi mogla biti manja u odnosu na prvo ubiranje što bi onda rezultiralo višim troškovima po toni ubrane biomase (Klepac i Rummer, 2010). Ispitivanja u nasadima brzorastućeg drveća su pokazala učinak od 31 bale h^{-1} u sječi vrba i 37 bala h^{-1} u sječi topola.

Temeljem gore navedenih istraživanja razvio se današnji Biobaler tvrtke Anderson Group co. iz Kanade. S prednje strane stroja je 50 zglobno priključenih noževa (rotoudarača) koji sijeku, ubiru i usitnjavaju biomasu pri brzini rotora od 2000 min-1. Visina reza se podešava hidrauličkim podizanjem i spuštanjem osovine kotača. Radna komora za oblikovanje bale je stalnog volumena s mogućnošću podešavanja gustoće bale, dimenzije bale su standardne 120 x 120 cm. Učinak može biti do 40 bala h-1 (20 t h^{-1}) u nasadima brzorastućeg drveća ili 15-18 bala h^{-1} (8-10 t h^{-1}) u prirodnim uvjetima u berbi niskog šumskog raslinja. Vezanje bala je biorazgradivim ili sintetičkim vezivom, automatsko dvostruko vezanje s 13 do 22 okretaja. Stroj ima široke pneumatike dimenzija 500/60-22.5 16PR ili 700/45-22.5 16PR. Traktor bi trebao imati zaštićeno (oklopljeno) podvozje, zaštitni okvir za kabinu, stražnji prozor zaštićen metalnom mrežom s otvorima (okcima) od najmanje 25x25 mm, kao i pneumatike pogodne za šumske terene.



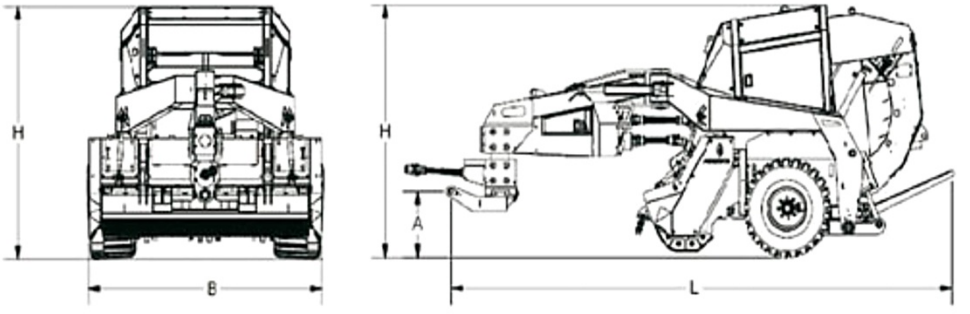
Sl. 2 Biobaler WB 55 zglobno priključeni noževi i mogućnost podešavanja visine reza
Fig. 2 Biobaler WB 55 cutting header and hydraulic lift sistem to adjust cut height

Utovar i transport bala se obavlja standardnom opremom koja se koristi i za bale sjenaže. Ovisno o vrsti biomase bale se mogu sušiti na polju prirodnim putem, a ovisno o vremenskim prilikama početni sadržaj vode u bali od 50 do 55% nakon osam tjedana iznosi 20 do 25%. Bala sadrži oko 1 MWh energije ovisno o vrsti biomase i može se koristiti za proizvodnju toplinske i električne energije, kao i u proizvodnji biogoriva, no bitna je i primjena stroja u održavanju zelenih površina, šuma i „čišćenju“ zapuštenog poljoprivrednog zemljišta. Ispitivanje i usporedba troškova rada krmnog kombajna i Biobaler-a WB 55 u ubiranju brzorastućeg drveća je najavljena od strane proizvođača.

Tehnički podaci za Biobaler WB 55

- radni zahvat: 225 cm,
- promjer sječe: do 15 cm,
- masa bale: 500 – 600 kg,
- potrebna snaga traktora: 150 – 187 kW (200 – 250 KS) P.V. 1000 min^{-1} ($1^{3/4}$ Z20),
- poteznica: 2. ili 3. kategorije,

- hidraulika: protok ulja 80 l min^{-1}, pritisak 130 - 190 bara,
- masa stroja: 6820 kg,
- dimenzije stroja: širina B 2585 mm, duljina L 5460 mm, najviša visina H 2970 mm, visina točke priključivanja A 620 mm



Sl.3 Dimenzije stroja Biobaler WB 55
Fig. 3 Biobaler WB 55 dimensions

ZAKLJUČAK

Zacrtani plan prema kojem bi do 2020. godine u EU 20% od ukupne potrošnje energije bilo dobiveno iz obnovljivih izvora mogao bi u proizvodnji biogoriva utjecati na povećano korištenje sirovina koje se koriste u ljudskoj prehrani, kao i povećano korištenje poljoprivrednih površina. Navedeno može biti uzrok porasta cijene soje, kukuruza i ostalih žitarica. Prisutan je stav koji ne podržava proizvodnju biogoriva iz biomase koja je ljudska hrana, osim u državama koje imaju viška zemljišta i jako razvijenu industriju biogoriva. Jedno od rješenja je brži razvoj biogoriva druge generacije koja koriste lignocelulozni materijal kao sirovinu i povećanje prinosa biomase. Površine na kojima se proizvodi ili se planira proizvoditi hrana, koje se koriste za ispašu, kao i šume trebale bi biti izuzete od proizvodnje energetskih kultura. Stroj za ubiranje i baliranje biomase u jednom prohodu - Biobaler WB 55 može se koristiti u ubiranju i sječi energetskih kultura u nasadima vrba, topola, eukaliptusa i dr., kao i u ubiranju samonikle biomase kao obnovljivog izvora energije sa raznih poljoprivrednih površina. Učinak stroja je do 40 bala h^{-1} u nasadima brzorastućeg drveća u sječi vrba, i 15-18 bala h^{-1} u prirodnim uvjetima u ubiranju niskog šumskog raslinja.

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BIOMASS FOR FUEL AND MACHINE FOR HARVESTING AND BALING

GORAN FABIJANIĆ, IGOR KOVAČEV

SUMMARY

Biomass represents 2/3 of renewable sources used for energy production in the EU. Production of first-generation biofuels affects the prices of certain raw materials such as corn and sugar cane, but not significantly to the overall increase of food prices. Solution is provided in second-generation biofuels, which have a wider choice of biomass materials that are not human food, but their development has been slower than expected. Production of biomass materials should be found, as much as possible, on surfaces that are not competitive to traditional crops and not created by deforestation. For the harvest of wild and cultivated biomass crops Biobaler WB55 can be used, which collects and bales biomass in one pass. It is able to work in plantations of biomass crops, in orchards, on abandoned agricultural land, under the electrical lines and along roads. The Biobaler can produce up to 40 bales per hour in short rotation crops (SRC) of trees like willow, poplar, and many others on plantations and 15 – 18 bales per hour in natural forest vegetation environments.

Key words: *biomass, biofuels, ethanol, machine for harvesting and bailing biomass*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Stručni rad
Expert paper

POWER BALANCING POSSIBILITIES FOR A SMALL WIND-PV PANEL HYBRID SYSTEM FOR A NEARLY AUTONOMOUS UNIT CONSUMER

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SUMMARY

Wind is, compared to solar irradiation, a highly stochastic energy source. Nevertheless, both are usable (to some degree) almost everywhere and therefore are very convenient energy sources. There are several possible configurations for a system with renewable energy sources, for example standalone and grid connected. In the current paper we estimate a small wind-PV panel hybrid system connected to the grid, with or without storage equipment. It is important to find correlation between the rated capacities of wind and solar PV equipment. Besides, sizing storage equipment is important, as it is expensive. The main goal of estimation is minimizing the amount of electrical energy from the grid by using the minimal amount of storage equipment. In the calculations, the weather data acquired from meteorological databases (hourly time series data over 6 years from several locations), a 1 kW unit consumer, normalised wind generators, standard PV-panels and batteries are used.

Key words: *wind-PV energy, energy storage, renewable energy penetration, system optimization*

INTRODUCTION

The pressure to increase the proportion of renewable energy sources in final energy consumption has been grown in the last years. According to the Directive 2009/28/EC of the European Parliament of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources, Estonia as all other EU countries is obliged to rise the share of renewables in the final energy consumption compared to the reference year 2005. For Estonia, the target of renewable energy share is set to 25%, as compared to 18% in 2005 (European Council, 2009).

Several sources of energy (biomass, wind power, solar radiation and ground heating) could be used for reaching the set target. Wind and solar technical resources are very convenient and available almost everywhere. The main problem is the very high stochastic level of wind.

One of the advantages of using both wind and solar energy is the possibility of producing electricity without generating heat energy. Moreover, it is characteristic to the wind energy generator equipment to have the shortest energy payback period (less than 0.5 year) compared to other energy generating technologies (Matthew, 2006).

The amount of installed wind energy generating capacities is rising at accelerating rate, therefore creating balancing properties of wind power capacities connected to the grid is needed. Despite some progress in arranging balancing measures, the development of wind capacities will exceed the grid possibilities in the near future. The best way to balance wind power units is hydropower stations. Unfortunately using hydropower as a balancing possibility is mostly limited due to lack of available necessary capacities for several reasons. Using the energy system resources of neighbouring countries is limited, because most countries are already engaged with development of wind power.

Cutting off the production of wind park chart peaks in case of energy excess, without using peak energy (Lepa *et al.*, 2009), has become one of the balancing measures in the last years. This does not look like a permanent solution, since more small wind and solar units connected to the grid have been set up, making the dispatch grid more complicated and therefore inducing balancing problems.

Another possible way of reducing a wind generator's effect on the grid is co-producing of energy with PV (photo voltaic) devices. Solar energy becomes more competitive due to continuously decreasing prises for PV panels (Wilkinson, 2010). Owners of wind and PV units are interested in selling more energy to the grid and purchasing as small amount of energy from the grid as possible. Evaluations show that in systems with equal capacities of wind and PV, the amount of energy supplied to and received from the grid diminishes with the increase of the relative part of wind energy and in the cases of average wind speeds 3.3-5.9 m/s stays to the range 42.3-52.6% from produced electricity (Annuk *et al.*, 2011). This shows that wind and PV units have some balancing properties when operating together. Some storage elements are probably needed in the system for maintaining control of energy flows.

The goal of the paper is to evaluate the possibilities for diminishing the amount of purchased energy from the grid by changing the ratio of the rated capacities of wind and PV units with varying minimised storage amounts. We look into possibilities to operate this system in off-grid regime. This is important for energy security. We use a unit consumer with the average capacity 1 kW by evaluating the behaviour of a system consisting of producers (wind-PV hybrid system), storage and a consumer. Economical aspects are not used in the calculations.

MATERIALS AND METHODS

In the present paper is assessed a grid-connected integrated renewable system consisting of a consumer, wind generators, PV panels, a DC/AC converter and storage devices (Fig. 1). The primary data processing was implemented by Microsoft Excel and HOMER software. One regular year of 8760 hours that includes all seasons was the evaluation period.

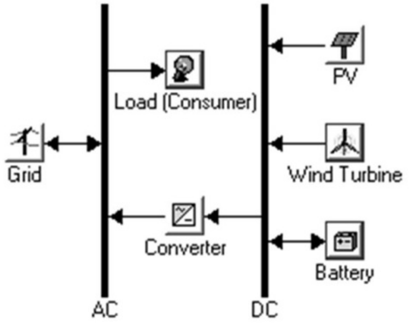

Fig. 1 Block diagram of the system

The annual electricity consumption data was synthesised from the measurements made in an Estonian typical countryside dwelling during one week in February and one week in August. It shows as one peculiarity that the daily and weekly peak loads are higher in summer than in winter. The reason for this is the equipment that is used in rural households in the summertime for water pumping, firewood sawing, etc. The daily averages and base loads are higher in winter because of a greater need for lighting and other applications.

Minimum and maximum loads are 0.098 kW and 3.51 kW correspondingly. The standard deviation in the sequence of daily averages is 25.5% and the difference between the hourly data and the average daily profile is 57%. This is a sufficiently rapid chart to satisfy the majority of consumer profiles.

The calculations were performed averaged hourly wind speed and global irradiation data measured by the Estonian Meteorological and Hydrological Institute in the locations of Tõravere and Tiirikoja in the years 2004-2009.

The solar irradiation data was used from one location – Tõravere, by the suggestion that in Estonia the annual actinometrical resource in the area changes up to 5.5% 890-990 kWh/year and the data from Tõravere describes the average irradiation from the Sun in Estonia (Tomson, 2000).

In Fig. 2 the solar irradiation data in Tõravere from the sample year 2008 is presented. Wintertime actinometrical resources are relatively insufficient, especially in December and January. In February and March the situation becomes better, because of diffused radiation reflected from snow. The proportion of direct and diffused radiation in winter months is small, 0.2-0.6. In summer months it is in the range of 0.6-1.2 (Annuk *et al.*, 2011; Russak&Kallis, 2003). In spite of the stable annual actinometrical resources, when comparing the years, solar irradiation behaviour is hard to determine due to diffused radiation during the day. For the PV panels we use devices with 12% efficiency at standard test conditions.

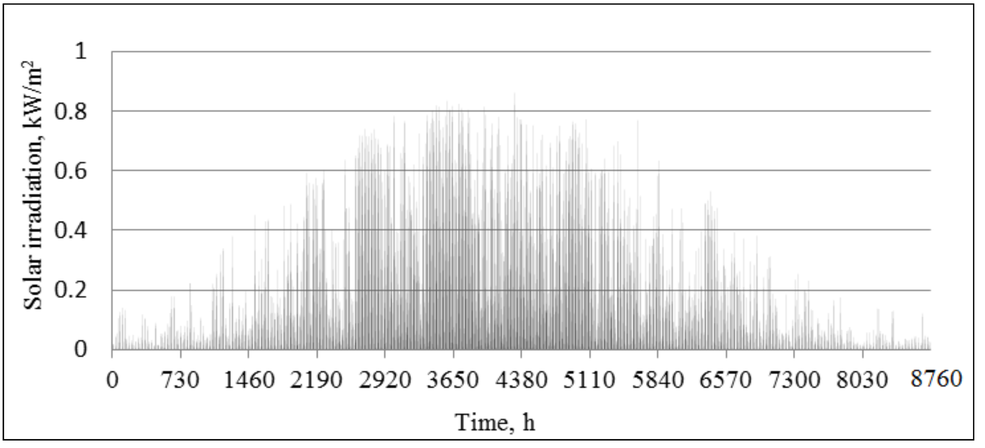

Fig. 2 Solar irradiation data in Tõravere 2008 (EMHI)

According to some authors (Beausoleil-Morrison *et al*., 2011; Tomson, 2000) the slope of 45 degrees is used to get maximum power output from PV panels in northern countries. Taking into consideration the opening electricity market in 2013, it will be reasonable to produce as much energy as possible in colder seasons. In this paper we evaluate panels without a tracking system; therefore the panels have an azimuth of 0 degrees to south.

The most commonly recommended PV array angle is equal to the latitude, because this gives the most even production chart through the year (Beausoleil-Morrison *et al*., 2011; Tomson, 2000). The third option is an angle that is best suited for PV production in winter (also in spring and fall). To calculate the best angle of tilt in the winter season, the latitude is multiplied by 0.89, and 24 degrees added (Al-Karaghouli *et al.,* 2007). The latitude of the measuring point is 58.26˚ and according to the cited above, the optimal tilt for winter conditions is 75.85˚. We use a derating factor f_{PV} = 90% (Al-Karaghouli *et al.,* 2007). The result is the angle from the horizontal at which the panel should be tilted. The reason is that in winter most of the solar energy comes at midday, so at noon the panel should be pointed almost directly to the sun.

To calculate the output of the PV panel we use the following equation (Homer Energy, 2011):

$$P_V = Y_{PV} f_{PV} \frac{\overline{G}_T}{\overline{G}_{T,STC}} [1 + \alpha_P (T_c - T_{c,STC}] , \quad (1)$$

where

Y_{PV} – The rated capacity of the PV array, power output under standard test conditions, kW;

f_{PV} – The PV degrading factor, %;

$\overline{G}_T$ – The solar radiation incident on the PV array in the current time step, kW/m^2;

$\overline{G}_{T,STC}$ – The incident radiation at standard test conditions, 1 kW/m^2,

a_P – The temperature coefficient of power, %/°C;

T_c – The PV cell temperature in the current time step, °C;

$T_{c,STC}$ – The PV cell temperature under standard test conditions, 25 °C.

Due to cold climate in the evaluated region and for simplifying the calculations we did not consider the temperature effect, $a_P = 0$.

The power output of the wind turbine is calculated every hour. This entails a two-step process to first calculate the wind speed at the hub height of the wind turbine, then to calculate how much power the wind turbine would produce at certain averaged hourly wind speed.

By using wind speed hourly averaged data we analyzed the Weibull´s shape factor k in different locations on the territory of Estonia. The wind speed data was measured at the anemometer height 10 m and average sea level (100 m in our study). It became obvious from the analysis that the average shape factor k = 1.77 with standard relative deviation δ = 0.06. The database consists of 30 measurements of 6 years and 5 different places (coastal and inland regions). Therefore it is eligible to use wind data of Tiirikoja (Fig. 3) from the year 2006 because this year has the abovementioned Weibull shape factor.

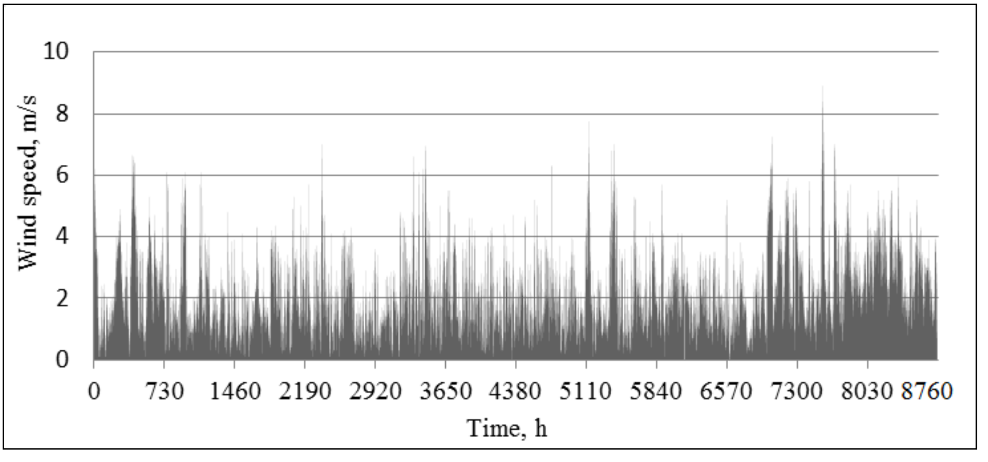

Fig. 3 Wind speeds in Tiirikoja, 2006

The power curve (2) of this virtual generator is averaged from several wind turbines that are most suitable for mild wind conditions wind generator charts. It should also be noted that this normalized power curve has the following limiters: if the wind speed v<2.5 m/s P = 0 kW and when v > 12 m/s, P = 1 kW (Põder et al., 2009).

$$P = 0.0078 \cdot v^2 - 0.0229 \cdot v + 0.00866022 \quad (2)$$

where

v – hourly averaged wind speed, m/s;

P – output power, kW.

The hub height of 30m was chosen. A logarithmic relation is used for transforming the wind speed data to the chosen height of 30 m. The surface roughness of z_0 = 0.25 was chosen since it is characteristic for landscapes in the countryside, where many trees, but not many buildings are situated.

DC/AC converter with the efficiency of 90% is used. Sealed deep-cycle lead-acid batteries with minimal state of charge SOC = 40% and the capacity of 200 Ah i.e 2.4 kWh and roundtrip efficiency of 80% are used as storage. Batteries are connected to strings by four pieces, with 48 V output voltages.

The energy balance of a hybrid system given in Fig. 1 is the following:

$$W_C = W_W + W_{PV} + W_G - W_{Bl} - W_{GS}, \quad (3)$$

where

W_C – energy consumption by unit consumer, kWh/year;

W_W – energy production from wind generators, kWh/year;

W_{PV} – energy production from PV arrays, kWh/year;

W_{Gp} – purchased energy from grid, kWh/year;

W_{Bl} – energy losses in battery, kWh/year;

W_{Gs} – sold energy to grid, kWh/year.

A unit consumer's average demand is 1 kW, this means a 8760 kWh consumption per year. The capacity factors are correspondingly solar and wind devices CF_S=0.084 and CF_W=0.115. The capacity factors stay constant during the study, but capacities change. To cover losses in the storage equipment, wiring and inverter, we suggest to use enough wind generators and PV arrays to cover at least:

$$W_W + W_{PV} \rightarrow 10000 kWh / year. \quad (4)$$

It should be noted, that average productivity from renewable energy sources must be tightly tied with consumption in order to avoid extensive overproduction.

RESULTS AND DISCUSSION

To find the optimal configuration of wind-PV capacities without batteries, different combinations in diverse amounts of produced energy are calculated by the suggestion of the equation (4). The indicators used were wind and solar penetration levels L_W and L_{PV} accordingly, and relative energies W_{Gp} and W_{Gs} from the grid and supplied to the grid. The results are shown in Table1 and Fig. 4.

Table 1 Dependencies of energy indicators from share of solar energy in system

Share of solar energy, WPV, %	Energy from grid, WGp, %	Supplied to grid energy, WGs, %	Renewable fraction, WR, %	Solar energy penetration, LPV, %	Wind energy penetration, LW, %
0	34	38	66.1	0	115
10	33	37	67	11.4	103
20	33	37	67.4	22.8	91.6
30	32	37	67.5	34.3	80.2
40	33	37	67.3	45.7	68.7
50	33	37	67	57.1	57.3
60	34	38	66.4	68.5	45.8
70	34	39	65.6	79.9	34.4
80	35	40	64.5	91.3	22.9
90	37	41	63	103	11.5
100	39	43	61.1	114	0

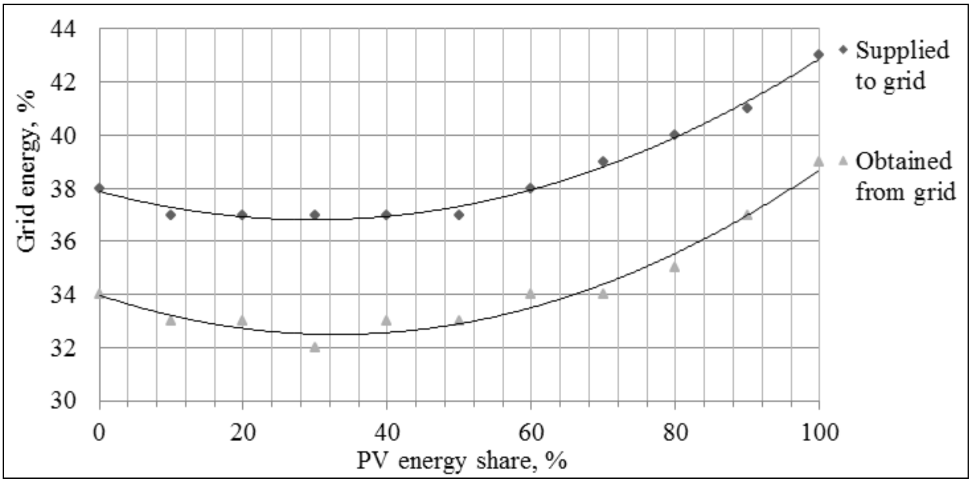

Fig. 4 Dependencies of grid obtained and supplied energy W_{Gp}, % and W_{Gs}, % accordingly to produced energy by different solar energy shares W_{PV}, %

All relative indicators are given in proportion of the consumed energy 8760 kWh, except the renewable fraction W_R, which is calculated by using the following formula:

$$W_R = \frac{W_{PV} + W_W}{W_C + W_{Cp}} \tag{5}$$

We see that the energy sold to the grid exceeds the precentage of electricity purchaced from it. In case of minimal energy from the grid, energy produced from PV panels and wind generators has a ratio of 3/7 correspondingly. Using this ratio we have the best balancing possibilities (e.g. the highest share of renewable fraction W_R – the highest shown in Table 1. This result is very close as in sources (Annuk, 2011; Caralis, 2011).

Table 2 Storage needs on different levels of limiting capacities for energy from grid

Limit capacity of energy from grid, PP, kW	Storage capacity, WSt, kWh	Obtained energy from grid, WGp, %	Renewable fraction, WR, %	Capacity shortage, WSh, %
3	0	32	68	0.46
	9.6	32	68	0
	19.2	32	68	0
2.5	0	31	68	1.92
	9.6	30	69	0
	19.2	30	70	0
2	0	31	69	5.57
	38.4	27	73	0.21
	48	26	74	0
	57.6	26	74	0
1.5	0	29	71	12.7
	67.2	21	79	1.4
	76.8	21	79	1.19
	86.4	21	79	0.99
1	0	25	75	25
	86.4	16	84	4.77
	480	13	87	1.13
	576	13	87	0.64

As we see in Table 2, adding storage capacities helps to increase the renewable fraction and decrease energy obtained from the grid. Limiting from-grid capacity without storage elements rises the capacity shortage rapidly.

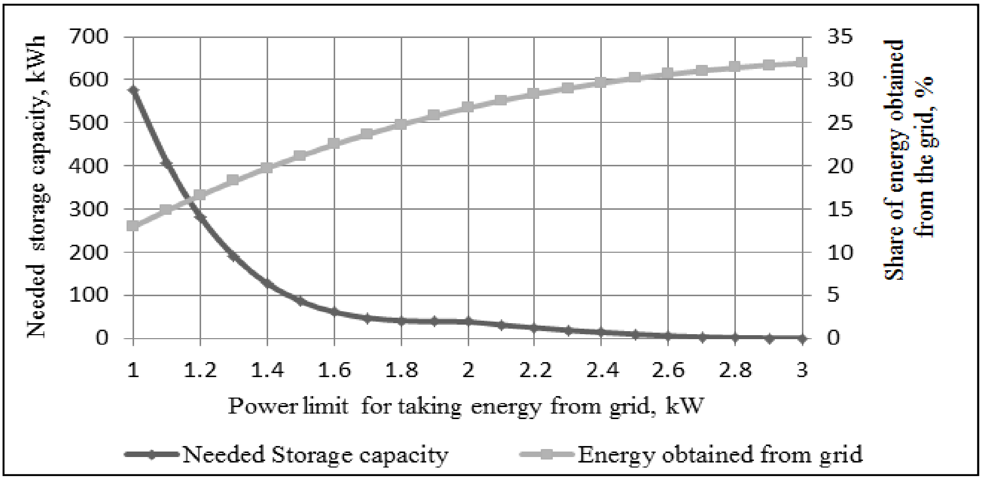

Fig. 5. Dependencies of limiting power from grid

Fig 5 shows the suggestion that when the capacity shortage is near zero $W_{Sh} \approx 1\%$, the used storage capacities amounts and share of obtained enegy from grid. In the case of limiting the capacity up to 1.6 kW, the needed storage capacity rises exponentially and it is not reasonable to use values above it. As a generalisation to the results given in Fig. 5 it is reasonable to limit the obtained capacity near the 1.6 kW treshold, then the needed storage capacity is 59 kWh and the share of energy from the grid is 23%.

CONCLUSIONS

In the example of a wind and PV panel system using a unit consumer with certain properties connected to grid, it is possible to find out the best possible electricity ratio, produced by wind and solar devices having the best balancing possibilities. The measure of the balancing possibilities is the amount of energy from the grid. Decreasing the amount of energy from the grid was the main goal of the study. Storage amounts have additional balancing properties. Storage amounts need to be minimized by minimizing the share of energy obtained from the grid and maximizing the renewable fraction.

The following generalizations can be made.

1. Nowadays PV-wind hybrid systems are used in two ways: autonomous and grid connected. It is important for a grid-connected system to minimize energy from the grid and to have the highest share of renewable fraction as possible, while having an optimal configuration and not using other fuels. It is important, since by doing so energy dependence is decreased and therefore energy security is increased.

2. Over dimensioning of a system is another issue to be observed. It is reasonable to limit the amount energy from installed capacities near the consumption energy taking into account the losses in devices. Rated capacities of devices are possible to be found according to climate conditions.
3. It is reasonable to use storage elements to increase the renewable fraction and decrease the amount of energy from the grid. In the case of a unit consumer it is reasonable to limit the capacity from the grid near the 1.6 kW threshold. In this case the system needs a storage amount of 59 kWh and the share of energy from the grid is lowest 23%. If the capacity from the grid is limited further, the amount of storage capacity needed will increase exponentially.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 582.542.2:620.91/95:662.7
Pregledni rad
Review paper

MISCHANTUS X GIGANTEUS KAO ENERGETSKA KULTURA

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SAŽETAK

Hibrid Miscanthus x giganteus *iz porodice trava (*Poaceae*) pokazao se kao zanimljiva i visokovrijedna kultura za proizvodnju obnovljive energije iz poljoprivrede. Prema prvim većim istraživanjima hibrid* Miscanthus x giganteus *je moguće uzgojiti na lošim i nekvalitetnim tlima u Republici Hrvatskoj, kako biomasa za potrebe obnovljivih izvora energije ne bi konkurirala proizvodnji hrane. Danas je prema Statističkom ljetopisu (2010.) preko 600 000 ha poljoprivrednih površina lošije kvalitete, čak štoviše to poljoprivredno zemljište počelo je prelaziti u neiskoristivu šikaru. Ovom kulturom omogućilo bi se iskorištenje takvih poljoprivrednih površina. Prednosti uzgoja trave* Miscanthus x giganteus *su visoki prinosi te male potrebe za gnojivom i gotovo nikakvim potrebama za pesticidima, što dodatno pridonosi ekološkoj održivosti poljoprivredne proizvodnje i kasnije proizvodnje zelene električne energije. Obzirom na činjenicu da usjev ostaje na polju minimalno 15 godina, od izuzetne je važnosti stručno i kvalitetno provesti sve agrotehničke mjere. U RH prva veća istraživanja (11 lokacija) o uvođenju* Miscanthus x giganteus-*a započeta su na Agronomskom fakultetu u Zagrebu 2011. godine.*

Ključne riječi*: obnovljivi izvori energije, biomasa,* Miscanthus x giganteus

UVOD

Činjenica je da danas otprilike polovica primarne energije za potrebe EU se dobiva iz uvoza. Energetski analitičari predviđaju da će se taj postotak povećati na 70% do 2030, uz pretpostavku da neće biti značajnih promjena globalne politike. Politička nestabilnost nekih od ključnih regija izvoznica nafte potencijalno prijeti stabilnoj proizvodnji i cijeni te stoga ugrožava energetsku sigurnost EU-a. Svakako tu je prisutan i ekološki aspekt, jer je korištenje fosilnih goriva jedno od glavnih onečišćivača okoliša kroz emisije u zrak, kao i ispuštanje stakleničkih plinova (GHG) (E.C., 2001; 2007).

U posljednjih deset godina Europska Komisija je donijela čitav niz dokumenta i propisa kojima se uređuje održivi sustav mjera kojima zemlje članice EU potiču ostvarenje zajedničkih proklamiranih ciljeva. Tako primjerice Direktiva 2009/28/EZ govori o promicanju upotrebe energije iz obnovljivih izvora, te definira ciljeve, kao i obaveze zemalja u neposrednoj potrošnji električne i toplinske energije, kao i goriva za prijevoz. Uz to, proizvodnja i uporaba biogoriva ispunjava i druga dva cilja i razloga za njihovu promociju, a to su doprinos sigurnosti kontinuirane opskrbe energijom i povećanje ekonomske aktivnosti odnosno regionalni razvoj, što je za Hrvatsku trenutno od krucijalne važnosti. Stoga je i Vlada Republike Hrvatske, u skladu sa Zakonom o biogorivima, izradila Nacionalni akcijski plan o poticanju proizvodnje i potrošnje biogoriva za razdoblje od 2011. do 2020. godine. (2009/28/EZ; Zakon o biogorivima).

Sukladno Strategiji EU o biogorivima iz 2006. godine, u Europskoj uniji se danas promovira druga, uz treću, generacija biogoriva, između ostalog i uzgoj energetskih kultura za proizvodnju lignocelulozne biomase. Lignoceluloza je jedan od najčešćih biopolimera u prirodi. Za razliku od npr. zrna žitarica, u kojima je škrob najznačajniji ugljikohidrat, lignocelulozna biomasa sastoji se od celuloze (40-50%), hemiceluloze (25-35%) i lignina (15-20%) (Gray i sur., 2006).

Osnovni izvori biomase su ostatci iz poljoprivrede i šumarstva, organski otpad, otpad iz prehrambene industrije, alge, gljivice i kvasci te svakako i energetski usjevi. Daljnji rast produkcije biomase (uz alge, gljive i kvasce – treća generacija biogoriva) trebao bi biti vezan uz intenzivnije korištenje relativno novijih energetskih usjeva, kao što su brzorastuće vrste drveća te travnato – ratarske kulture. Svrha uvođenja novih kultura je pronaći usjeve koji će biti ekološki i ekonomsko prihvatljivi, pogotovo na onim klimatsko - geografskim područjima koja su nepogodna za proizvodnju hrane, kako proizvodnja energije ne bi konkurirala proizvodnji hrane (Demirbas et al. 2009). Jedan od tih energetski usjeva je i višegodišnja trava *Miscanthus*.

Prednosti energetskih trava, pa tako i *Miscanthusa,* nad jednogodišnjim usjevima koji se mogu koristit za energiju (žitarice, šećerna repa i uljarice) su relativno visoka neto fosilna energija i ušteda emisije stakleničkih plinova po jedinici biomase i poljoprivrednog zemljišta (Boehmel et al.,2007), obzirom na činjenicu o kombinaciji relativno visokog prinosa s relativno niskim pritiskom na okoliš u odnosu na jednogodišnje usjeve. Najkvalitetniji energetski usjevi su oni koji se mogu požeti suhi i koji imaju mogućosti višegodišnjeg rasta, kako bi se izbjegli troškovi sušenja, odnosno sadnje i obrade svake godine, što normalo ima za posljedicu povećanja profitabilnosti uzgoja. Na taj ekonomski, ali svakako i na ekološki aspekt utječe činjenica o niskim potrebama za gnojidbom i zaštitom (prvenstveno protiv korova) tijekom samog uzgoja ovakvih kultura izuzev prve godine (CRES Greece, 2006). Danas je prema Statističkom ljetopisu (2010.) preko 600 000 ha poljoprivrednih površina lošije kvalitete, čak štoviše to poljoprivredno zemljište počelo je prelaziti u neiskoristivu šikaru. Ovom kulturom omogućilo bi se iskorištenje takvih poljoprivrednih površina. Ključni nedostaci uključuju relativno visoke troškove osnivanja, uske genetske osnove, te niska otpornost na prvu zimu nakon uspostave *Miscanthusovog* usjeva.

Miscanthus x giganteus se trenutno uglavnom koristi za sagorijevanje s ugljenom i izravnim sagorijevanjem (peletiranom, briketiranom ili baliranom obliku) za proizvodnju električne i toplinske energije. Nadalje, može se također koristiti za širok raspon energija i materijala, kao što je proizvodnja topline i energije putem izgaranja i/ili plinifikaciju, za proizvodnju tekućeg biogoriva, ali i za proizvodnju papira građevinskog materijala, plastike kao i kod kompostiranja (Smeets et al., 2009).

POVIJEST I SISTEMATIKA PRIPADNOSTI RODA *MISCANTHUS X GIGANTEUS*

Miscanthus se pojavljuje unutar visokih travnjaka istočne Azije, od tropa i subtropa do Pacifičkih otoka, toplih temperaturnih regija i subarktičkog područja. *Miscanthus sp.* se po prvi puta pojavljuje u Europi tridesetih godina prošlog stoljeća, kada je uveden iz Japana i to isključivo kao ukrasna hortikulturna biljka, dok je početkom pedesetih godina prošlog stoljeća u Dansku uvezen hibrid *Miscanthus x giganteus* zbog njegovog iznimno brzog i snažnog rasta (Greef i Deuter, 1993). Prvi opsežniji poljski pokusi, kako u Europi tako i SAD provode se od sredine osamdesetih pa sve do danas.

Taksonomija unutar *Miscanthus* roda je poprilično nedefinirana. Budući da Miscanthus ima osnovni broj kromosoma 19, triploid genotipa *Miscanthus x giganteus* posjeduje 57 somatskih kromosoma i vjerojatno je prirodni hibrid koji uključuje *Miscanthus sacchariflorus* (diploid) i *Miscanthus sinensis* (tetraploid). Doprinos *Miscanthus Sacchariflorusa* genomu *M. x giganteus* omogućio je prilagodbu u toplijoj klimi, dok mu *Miscanthus sinensis* daje genetski resurs za hladnije regije. *Miscanthus x giganteus* je sterilan i ne može stvarati plodne sjemenke kao posljedica njegove triploidnosti (Lewandowski et al., 2000).

OKOLIŠNI I GNOJIDBENI ZAHTIJEVI ZA RAST

Izvanredna je prilagodljivost *Miscanthusa x giganteusa* različitim okolišima što čini ovaj usjev pogodnim za osnivanje i distribuciju u različite europske i sjevernoameričke klimatske uvjete. Rod *Miscanthus* je višegodišnja rizomatska trava s C4 fotosintetskog putem. Biljke s C4 fotosintezom imaju potencijal višeg prinosa nego biljke s C3 fotosintezom zbog visokog zračenja, ali ujedno i zahtijevaju toplije uvjete od C3 biljaka za pokretanje rasta u proljeće (Lewandowski et al., 2000). Biljke koje nemaju C_4 put fiksacije ugljika fotorespiracijom gube između 25% i 50% fiksiranog ugljika. C_4 put je posebno važan za smanjivanje fotorespiracije pri višim temperaturama. Takav metabolizam omogućuje im život na sušnijim staništima (Caslin et. al. 2010).

Utjecaj svjetlosti na dobivanje biomase iz usjeva za biljke C_4 metabolizma 40% je veći nego za C_3 vrste, iako čine većinu vegetacije i usjeva zapadne Europe. C_4 biljke su osjetljive na oštećenja pri niskim temperaturama što može smanjiti njihov potencijal, primjerice u područjima sjeverozapadne Europe. Međutim, *Miscanthus* je izuzetak među C_4 biljkama. Taj izuzetak očituje se u njegovoj održivosti u hladnim klimatskim uvjetima. Utvrđeno je kako je temperatura najvažniji čimbenik kod rasta listova. Većina C_4 biljaka nije sposobna obavljati fotosintetske procese kod temperature niže od 12°C (Long, 1999). Istraživanja u kontroliranim uvjetima pokazuju da je *Miscanthus x giganteus* različito reagirao od npr. hibrida kukuruza namijenjenih zapadnoj Europi. Biljke su neprekidno rasle na temperaturama od 8 °C, 12°C i 25°C (Jones et al. 2001). Neočekivano i u suprotnosti sa svim prethodno istraživanim C_4 vrstama, listovi *Miscanthus x giganteus*-a rasli na 12°C te su imali su isti fotosintetski kapacitet kao i lišće biljaka uzgajanih na 25°C. Rast na 8 °C rezultiralo je 50%-tnim smanjenjem fotosintetskog kapaciteta, što ukazuje da se temperaturne granice za oštećenje fotosintetskog aparata kreću između 8 i 12 °C. U prvoj zimi nakon sadnje, plitko sađeni i nedovoljno razvijeni rizomi često su uništeni uslijed hladnoće i/ili vlažnih uvjeta (Jones et al. 2001; Caslin et. al. 2010). Nema podataka o problema tijekom prezimljavanja u drugoj i naknadnim zimama. Za potpunu uspostavu *M. x giganteus-a* potrebne su najmanje dvije uzgojne sezone prije pojave brzog rasta izboja.

Učinkovitost korištenja vode je bila praćena pokusima u eksperimentalnim teglama i u rasponu je od 250 do 340 GG-1 (mase vode po jedinici suhe tvari, također odgovara ekvivalentu litara vode po kilogramu suhe tvari) i 80 do 300 gg-1 za poljska istraživanja. Iako njegova učinkovitost iskorištenja vode je veća nego kod većine C3 usjeva, rast je često ograničen uslijed nedostatka vode (Lewandowski et al., 2000). Centar za hidrologiju i ekologiju Velike Britanije je zaključio da je učinak na razinu slivnih područja je zanemariv, ali samo pod uvjetom da opsežna područja pojedinih slivova nisu u neposrednoj blizini ili pod samim nasadima (Smeets et al., 2009).

Visoka učinkovitost iskorištenja dušika uglavnom se može pripisati translokaciji istog u izboje tijekom proljeća te re-translociranja u rizome na kraju vegetacije kada usjev odumire. Procijenjeno je da se translokacijom iz izboja u rizome unosi oko 21 - 46% N, 36 - 50% P, 14 - 30% K i 27% Mg. Nadalje, utvrđeno je da na kraju zime rizomi 6-godišnjeg *Miscanthus-ovog* nasada sadrže 265 kg N/ha i 235 kg K/ha. U proljeće, su te rezerve nanovo aktivirane kako bi se dovele natrag u nove izboje, čineći *Miscanthus* dijelom neovisnim o opskrbi N iz tla (Beale i Long, 1997).

Primijenjene razine gnojiva iskazane u literaturi prikazene su u širokom rasponu. Posebno je nedefinirana primjena razine dušičnih gnojiva, jer ne postoji dogovor o ovisnosti uroda *Miscanthusa* na gnojidbu dušikom (Smeets et al., 2009). Beale i Long (1997) su izračunali da bi dušični zahtjevi *Miscanthus-a x giganteus-a* s prinosom od 25 t/ha suhe tvari bili 93 kg/ha (izračunato na temelju vrijednosti godišnje akumulacije dušika). Nadalje, također se može zaključiti da je N potrebno gnojiti uglavnom na tlima s niskim sadržajem istoga. Na lokacijama s dovoljnom mineralizacijom N organske tvari iz tla, nije uočen utjecaj N gnojidbe na prinos. Međutim, kako bi zadovoljili zahtjeve N, od 50 do 70 kg/ha godišnje dušika može se dati na početka klijanja rizoma. Iako zahtjev *Miscanthus-a* za kalijem je od oko 4 do 8 kg/t suhe tvari, gnojidba K nije poboljšala prinos *M. x giganteus* što može biti utjecaj dobre opskrbe K u tlu. Ukupni zahtjevi za hranjivima N, P i Ca se približno kreću oko 2 - 5, 0,3 - 1,1, 0,8 – 1 kg/t suhe tvari, redom. Obzirom na prethodno spomenuti nedefinirani dogovor logično je ta da sva hranjiva uklonjena s polja trebaju biti zamijenjena kako bi se izbjeglo iscrpljivanje tla, te da su svakako potrebna daljnja istraživanja o optimalnim količinama gnojidbe obzirom na različite tipove tala (Nolan et. al., 2009; Lewandowski et al., 2000).

KOROVI I BOLESTI

Ako se ne kontrolira, korov će se „natjecati“ s usjevom za svijetlo, vodu i hranjive tvari, te time smanjiti prinos. Natjecateljska moć korova ovisit će o stupnju zrelosti usjeva (sposobnosti usjeva da se natječe sa korovom), o količini korova u usjevu i raznolikosti korovne vrste. Biljke u početku vegetacije nisu se sposobne natjecati se sa korovomima. U toj fazi vegetacije mehanička kontrola korova može biti jedina opcija zaštite usjeva (Jones et al. 2001). Međutim, valja naglasiti da je tijekom uzgoja *Miscanthusa x giganteusa* herbicide potrebno primijeniti samo tijekom faze osnivanja usjeva (prva i druga godina) (Smeets et al. 2009). Prva primjena se provodi totalnim herbicidom, te ju je potrebno provesti desetak dana prije oranja kako bi se suzbili postojeći višegodišnji korovi, što je posebno važno ukoliko se usjev podiže na površinama koje su prethodno bile pod pašnjacima. Drugoj primjeni, selektivnim herbicidom, pristupa se petnaestak dana nakon sadnje, a prije nicanja mladih izboja. Konstantno nadziranje bolesti i kukaca općenito nije potrebna (Smeets et al. 2009) iz razloga što do danas nema podataka o pojavi značajnijih biljnih bolesti i nametnika koji značajnije ograničavaju proizvodnju. Međutim, poznati su slučajevi da usjev može biti osjetljiv na Fusarium, virus žute pjegavosti ječma, te Miscanthusov palež (Lewandowski et al., 2000).

VRIJEME I GUBICI TIJEKOM ŽETVE

Žetvu *Miscanthus*-a treba obaviti nakon sazrijevanja odnosno „odumiranja" usjeva, kada je sadržaj vlage najniži, a prije početka novog porasta u proljeće naredne godine (temperatura tla >10°C). Važno je da je usjev dovoljno zreo, tako da ima dovoljno pohranjenih rezervi hranjiva u rizomima radi preživljavanja zime i ponovnog početka rasta. Vrijeme žetve najviše ovisi o klimatskim regijama, odnosno je li kultura uzgajana u sjevernoj ili južnoj Europi te najčešće se provodi između 11. i 4. mjeseca (Caslin et. al. 2010). Za određivanje optimalnog vremena žetve poglavito je važan što niži sadržaj vlage, kako se biomasa ne bi trebala dodatno sušiti, što naravno dodatno povećava cijelu ekonomsku bilancu uzgoja *Miscanthus-a*. Prema istraživanjima provedenim u Njemačkoj i

Nizozemskoj, sadržaj vlage se je smanjio sa 70% (osnova je svježa težina) u studenom na ≥ 20% u ožujku ili travnju. Odgađanjem žetve postiže se poželjan niži sadržaj minerala i vlage (Lewandowski et al., 2000). Jedan od nedostataka ostavljanja usjeva u polju do kasno u sezonu je rizik od gubitaka uroda biomase, koji nastaje kao rezultat nepovoljnih vremenskih uvjeta tijekom zime. Tijekom zime, većina lišća i neodrvenjeni dijelovi padaju s Miscanthusa. Rasponu tih gubitaka je u između 3 - 25% u prosincu te 15 - 25% u ožujka. U Nizozemskoj su ti gubitci iznosili u prosijeku 35% u razdoblje od listopada do ožujka, ali su uvelike raznoliki obzirom na vremenske uvjete između pojedinih godina i lokacije. Premda, stvarni žetveni gubici su oko 25%, dok strnište ostalo na polju predstavlja daljnji gubitak od 17%. Tako ukupni predžetveni i žetveni gubici mogu iznosi oko 37% biomase dostupne prije zime. U sjevernoeuropskoj regiji prvi mraz u jesen ili zimi znak je završetka rasta *Miscanthus-a*. U tim područjima žetva će se provesti u rano proljeće, od početka 2. mj. do kraja 4. mj., kako bi postigli najnižu moguću vlagu dobivenog materijala (sadržaj vlage usjeva smanjuje se tijekom zimskih mjeseci). U to doba sadržaj vlage usjeva može biti nizak i do 10%, usporedno s prosječnih 50 do 60 % prijašnje jeseni, što ovisi i o meteorološkom prilikama navedenog razdoblja (El Bassam and Huisman, 2001; Huisman, 2003). Gubitak suhe tvari od 25% je zabilježio Leahy (2006) u vrijeme proljetne žetve u sjevernoj Europi dok su Lewandowski and Heinz (2002) zabilježili gubitak usjeva od 14 do 15% između 12. i 2. mj. i za daljnjih 13% između 2. i 3. mj. Ukupni gubitak s.t. do 35% može rezultirati uslijed odgađanja žetve. Rezultati *Miscanthus-ovog* prinosa iz odgođene žetve kreču se u rasponu od 7 do 25 t.s.t./ha (Nolan et. al., 2009).

SUŠENJE I SKLADIŠTENJE

Nakon žetve, *Miscanthus* za energetske potrebe može se skladištit u usitnjenom, baliranom, briketiranom i peletiranom obliku. Kako bi materijal bio sigurno skladišten, žetva se ne smije provesti ako je sadržaj vlage iznad 15 do 17%, ukoliko sušenje nije moguće. Tip skladištenja ovisi o navedenim oblicima požete biomase i raspoloživosti skladišnog kapaciteta. Usitnjeni i balirani Miscanthus može biti skladišten na nekoliko načina i to na otvorenom prostoru bez pokrivanja, na otvorenom prostoru prekriven s plastičnim prekrivačima ili ceradama, te u postojećim ili novosagrađenim skladišnim prostorima. Tijekom skladištenja, u kontroliranim uvijetima, sadržaj vlage trebalo bi se smanjiti na razinu koja je u ravnoteži s relativnom vlažnosti zraka od 70 do 80%, ovisno o temperaturi skladištenja. Ako je sadržaj vlage previsok, mogućnost je pojava mikrobiološke aktivnosti, što će rezultirati gubitcima suhe tvari i smanjenom kakvoćom biomase (Nolan et. al., 2009; Caslin et al. 2010).

Za rukovanje usitnjenim materijalom, mogu se primijeniti slične metode kao za kukuruznu silažu. Za dugotrajno suho skladištenje sadržaj vlage bi trebao biti oko 15% ili niži. Razvoj plijesni i pojava samozagrijavanja mogu biti uzrokovani višim sadržajem vlage, međutim to se može spriječiti korištenjem prirodne ventilacije, ukoliko je sadržaj vlage do 25%, bilo da se radi o baliranoj ili usitnjenoj biomasi. Samozagrijavanje u skladištu se može kontrolirati tako dugo dok je omogućeno ventiliranje, jer je otpor protoka zrak u balama i hrpama usitnjenog materijala niska. Velike hrpe usitnjenog materijala mogu biti ostavljene nepokriveno, ali se pri tome svjesno prihvaća gubitak biomase, uzrokovan truljenjem, u vanjskim slojevima koji mogu apsorbirati vlagu u 5 - 50 cm dubine. (Smeets et al. 2009; Jones et al. 2001).

Najrentabilnija i najčešće korištena opcija je skladištenje na otvorenom s plastičnim folijama. Ova metoda se također često primjenjuje za skladištenje silaže. Nadalje, provedena su istraživanja o skladištenju prirodno osušenih bala sa različitim sadržajem vlage iz dva žetvena perioda (1 i 3 mj.). Bale požete u 1. mj. su imale sadržaj vlage između 45 do 50% s gubitkom suhe tvari između od 12 do 15 %. Žetva u 3. mj. je rezultirala balama sa sadržajem vlage između 25 i 30 % i gubitkom suhe tvari od 7 do 10 %. Bale sa nižom gustoćom mogu biti skladištene s višim sadržajem vlage nego bale s višom gustoćom uz manji gubitak suhe tvari (El Bassam and Huisman, 2001).

Kod siliranja (anaerobi uvjeti) usitnjena biomasa *Miscanthus-a*, pod plastičnim folijama, dolazi do potrošnje kisika, te samim time do ugibanja aerobnih mikroorganizama. Dovoljno je šećera dostupno u Miscanthusu za proizvodnju zadovoljavajuće količine mliječne kiseline koja sprječava većinu mikrobiološke aktivnosti. pH vrijednost potrebna za čuvanje *Miscanthus*-a u silosu ovisi o vlažnosti pohranjenog materijala. Za pohranu pri vlažnosti od 80% potreban je pH 4,2, a za pohranu materijala vlažnosti od 50% pH treba biti 5,2. Važan uvjet za pohranu je anaerobnost, jer ulaskom kisika, počinje aerobna aktivnost mikroorganizama i povećava se temperatura. Moguće je dodati šećer ili kiselinu za povećanje pH vrijednosti (Smeets et al. 2009).

Postoje različite mogućnosti sušenja *Miscanthus*-a i to sušenje u polju (najrentabilniji način, unatoč nedostatcima vezanim uz kasnije prikupljanje), sušenje u skladištu (kod visokog sadržaja vlage potrebno je grijani zrak prilagoditi na onu razinu tijekom koje se neće dogoditi gljivične infekcije), sušenje u industrijskim pogonima (rotirajući, pneumatski, parni bubnjevi) (Jones et al. 2001).

Ukoliko nije moguće osušiti *Miscanthus x giganteus* na polju, odmah nakon žetve je potrebno dodatno sušenje (sadržaj vlage > 25%) ili tijekom skladištenja (sadržaj vlage < 25%) ukoliko je uspostavljena ventilacija. Literaturni podatci ukazuju da prirodno ventilirane hrpe usitnjenog *Miscanthus-a* u Danskoj, u rasponu od 187 dana, sadržaj vlage se smanjio sa 63 na 51%, dok je zabilježeni gubitak suhe tvari iznosio 5,4% (Jones et al. 2001).

POTENCIJALNI PRINOS I ENERGETSKE KARAKTERISTIKE

Za punu uspostavu *Miscanthus-ovog* usjeva potrebno je 3 - 5 godina, ovisno o klimatskim uvjetima, tijekom kojeg se povećava prinos sa svakom narednom godinom do desete godine uzgoja, a potom se prinos postupno smanjuje. Prinos i kvaliteta same biomase, osim spomenutih klimatskih prilika, varira ovisno o datumu i načinu žetve, tipu tla, raspoloživoj vodi, kao i kvaliteti sadnog materijala. Prosječni prinos se kreče oko 15 t/ha (suhe tvari) godišnje. Međutim, opsežna istraživanjima diljem Europe su ukazala na velike razlike u prinosu biomase od 2 t/ha (srednja Njemačka, izrazito loše tlo) do 44 t/ha (sjeverna Grčka) (Smeets et al. 2009)

Energetske vrijednosti požetog usjeva zrelog Miscanthusa su u rasponu od 17,7 MJ/kg do 19 MJ/kg (GOV), na suhu tvar (CRES Greece, 2006). Istraživanja ukazuju na povećanje energetske vrijednosti (DOV) od 4 MJ/kg do cca 13,8 MJ/kg tijekom odgođene žetve. Povećanje energetske vrijednosti izravno je vezano uslijed snižavanja sadržaja vlage usjeva.

Odgađanje žetve do proljeća utječe na smanjenje prinosa biomase, što je također prouzročeno smanjenje sadržaja vode, ali i smanjenja koncentracije pepela, dušika, klora i sumpora. Ovaj gubitak, ispiranjem, nepoželjnih komponenti biomase s oborinama poboljšava goriva svojstva *Miscanthus-a* što dovodi do smanjenja emisija štetnih plinova, smanjenje zahtjeva prema sušenju i višom energetskom vrijednošću. Ukoliko se *Miscanthus* koristi kao izvor biomase za gorivo ili vlakana, potreban je jednogodišnji ciklus. Kako bi se osigurala visoka kvaliteta i kvantiteta proizvoda za daljnje korištenje nužna je ispravna prerada i skladištenje požetog *Miscanthus-a* (Nolan et al., 2009). Temeljem praćenja kemijskih karakteristike biomase *Miscanthus-a* utvrđen je povoljan sastav za izgaranje. Mineralni sadržaj je nizak u usporedbi sa slamom pšenice, ali viši nego za brzorastuće šumske kulture (vrba, topola). Mineralne koncentracije su niske tijekom žetve u rano proljeće te iznose 0,2 - 0,6% N; 0,5 - 1,3% K, 0,1 - 0,5% Cl i 1,6% - 4,0 pepela. Poput drugih goriva iz biomase, reaktivnost i stabilnost paljenja su visoke u usporedbi s ugljenom. Sastav pepela *Miscanthusa* obuhvaća oko 25 - 40% SiO_2, 20 - 25% K_2O, 5% P_2O_5, 5% CaO i 5% MgO te sadrži veće količine hranjivih tvari i niže količine teških metala od prirodnog drvenog pepela. Glavni problem izgaranja *Miscanthusove* biomase je niska točka tališta pepela. Pepeo *Miscanthus-a* daje jasne tendencije sinteriranja na niskim temperature poput 600°C, što kod npr. vrbe i topole nije slučaj. Karakteristike biomase mogu varirati od godine do godine i između različitih lokacija (Lewandowski et al., 2000).

EKOLOŠKI ASPEKTI PROIZVODNJE

Proizvodnja biomase predstavlja rizik od onečišćenja tla i podzemnih voda nitratima, fosfatima, kalijem i pesticidima. Budući da *Miscanthus* pokazuje nisku osjetljivost na štetočine i bolesti, na taj način ima niske ili gotovo nikakve zahtjeve za pesticidima, čime se smanjuje rizik od onečišćenja podzemnih voda i organizama u tlu. Literaturni podaci pokazuju i nisku razinu ispiranja nitrata u usporedbi sa drugim kulturama, što je povoljno u smislu zaštite površinskih i podzemnih voda. Razina ispiranja nitrata utječe na gnojidbu i starost nasada, zajedno sa drugim čimbenike kao što su klima i vrsta tla. Nadalje, zamjena fosilnih goriva pomoću *Miscanthus*-a kao goriva može dovesti do smanjenja i emisije stakleničkih plinova i kiselih kiša (Jones et al. 2001; Caslin et al. 2010).

Zbog dugog razdoblja pokrivenosti tla i visokog unosa organske tvari iz listova *Miscanthus-a*, može se očekivati da će se organske tvari u tlu povećati, kao i struktura tla poboljšati u usporedbi s drugim ratarskim usjevima. Sadržaj humusa u tlu tijekom 4 - 8 godine starosti *Miscanthus-ovog* nasada povećao se zajedno sa kapacitetom tla za razmjenu kationa i pojavio se lagani porast zadržavanja (retencije) vode. Literaturni podaci su također pokazali da uzgojem *Miscanthus-a* utječemo na smanjenje stope erozije tla i povećanja bioraznolikosti u usporedbi s konvencionalnim jednogodišnjim usjevima, ali se je i povećala erozija u odnosu na trajne pašnjake (Lewandowski et al., 2000). Vrijedno je napomenuti, da se prednosti za okoliš očituju samo kod pažljivog upravljanja i poštivanja smjernica tijekom proizvodnje i prerade.

TEHNIKA U UZGOJU *MISCANTHUSA*

Obzirom da se obrada, predsjetvena priprema tla za sadnju kao i njega nasada obavlja klasičnim konvencionalnim strojevima u ratarstvu i travnjaštvu, naglasak u tehnici tijekom uzgoja *Miscanthus-a* je na strojevima i opremi za sadnju i žetvu. Međutim, obzirom na činjenicu da usjev ostaje na polju minimalno 12-15 godina, od izuzetne je važnosti stručno i kvalitetno provesti sve agro-tehničke mjere.

Literaturni podaci ukazuju da je sadnju *Miscanthus-a* potrebno provesti na dubini od 5 – 20 cm. Sadnju je moguće provesti između veljače i lipnja, ali su najbolji rezultati postignuti tijekom sadnje između ožujka i svibnja. Uobičajena gustoća sklopa je 10 000 biljaka/ha (Jørgensen, 2007; Caslin et. al. 2010).

Rizomi su identificirani kao najprikladniji sadni materijal tijekom podizanja usjeva, što su potvrdila brojna stručna i znanstvena istraživanja ukazavši da se njihovom uporabom ostvaruje najbolja ekonomska bilanca tijekom uzgoja *Miscanthus-a*. Željena gustoća, postojana odabrana dubina sadnje te dobar smještaj rizoma može se postići korištenjem adaptirane poluautomatske sadilice za krumpir. Međutim, u zadnjih nekoliko godina u Europskoj uniji se tijekom podizanja ekstenzivnih usjeva na većim površinama sadnja obavlja pomoću specijalnih sadilica za *Miscanthus*, koji mogu biti u različitim izvedbama ovisno o proizvođaču. Sve ih uglavnom karakterizira dobar radni učinak (manje izvedbe 5 ha/h, veće 10-25 ha/h) (Huisman, 2003; Caslin et. al. 2010).

Najčešće korišteni stoj u žetvi *Miscanthus*-a je univerzalni krmni kombajn s hederom s rotirajućim nazubljenim valjcima. Međutim, žetvu *Miscanthus-a* možemo podijeliti na dvije tehnike izvođenja jednofazna (košnja-baliranje ili košnja-usitnjavanje) i višefazna (košnja, formiranje otkosa, baliranje ili prikupljanje-usitnjavanje) (Huisman, 2003; Kristensen, 2007).

UVOĐENJE *MISCANTHUS X GIGANTEUS*-A U HRVATSKU

Kako bi se utvrdila mogućnost uvođenja *Miscanthus x giganteus-a* u Hrvatsku formirani su eksperimentalni usjevi u kontinentalnom nizinskom i brdskom području te u submediteranskom području na 11 različitih lokacija. Prosječna površina pokusnih polja je oko 3000 m^2. Obuhvaćene lokacije su: Medvednica (Krapinsko-zagorska županija), Donja Bistra (Zagrebačka županija), Knin - Kaldrma (Šibensko-kninska županija), Knin - Plavno (Šibensko-kninska županija), Udbina - Krbavsko polje (Zadarska županija), Ličko Petrovo Selo (Ličko-senjska županija), Donji Lapac (Ličko-senjska županija), Zelina Breška (Sisačko-moslavačka županija), Sv. Helena (Zagrebačka županija), Gospić (Ličko-senjska županija) i Galdovo (Sisačko-moslavačka županija). Rizomi su posađeni u vremenskom razdoblju od 26.4. do 3.5.2011. Najbolji sklop poslije nicanja i na kraju vegetacijske sezone (oko 95%), najveća visina biljaka na kraju sezone rasta (120-220 cm) i najmanja zakorovljenost usjeva zabilježena je na lokaciji Donja Bistra i u Centru za travnjaštvo Agronomskog fakulteta na Medvednici. Suša je uzrokovala značajni zaostatak u rastu i razvoju usjeva na svim lokacijama, a naročito u submediteranskom dijelu Hrvatske. Međutim, uspoređujući rast biljaka do jesenskog „odumiranja" s nizozemskim iskustvima (Christian et al. 2008) možemo zaključiti da su na većini eksperimentalnih polja zabilježene veće visine biljaka, unatoč izrazito sušnom periodu. Od navedenih 11 lokacija, njih 3 su u potpunosti uništene. Lokacija Gospić i Udbina - Krbavsko polje uslijed paše konja, dok je kod lokacije Sv. Helena sklop izrazito rijedak (cca. 30 %) zbog nepravilne podešenosti dubine sadnje (preplitko posađeni rizomi), što je uzrokovalo sušenje istih. Primijenjeni herbicidi HERKULES 480 SL (glifosat) prije oranja i Lontrel 300 0.35 l/ha (klopiralid) + Deherban M 2.5 l/ha (MCPA) poslije sadnje a prije nicanja pokazali su zadovoljavajuće rezultate u kontroli korova.

ZAKLJUČAK

Iz svega navedenog može se zaključiti:

1. Glavne karakteristike trave *Miscanthus x giganteus-a* temeljem literaturnih podataka su uglavnom visoki prinosi, relativno niski troškovi proizvodnje, mogućnost uzgoja na tlima lošije kvalitete, te relativno niski pritisak na okoliš, u odnosu na konvencionalne usjeve.
2. Biomasa *Miscanthus x giganteus-a* se može koristiti kao zamjena za fosilna goriva tijekom proizvodnje druge generacije biogoriva što može smanjiti ovisnost o uvozu i/ili emisije štetnih plinova
3. Veliki utjecaj na količinu biogoriva druge generacije iz *Miscanthus x giganteus-a* ima njegova žetva, a kao glavni čimbenika za poboljšanje kvalitete biomase pokazala se odgođena žetva neposredno prije kretanja nove vegetacijske sezone Miscanthusa.

4. Hrvatska raspolaže sa 600.000 ha (Statistički ljetopis, 2011), neupotrebljivih poljoprivrednih površina (tla lošije kvalitete). Uvođenje *Miscanthus x giganteus-a* kao energetskog usjeva na navedene površine, neće konkurirati proizvodnji hrane, a pomoći će otvaranju radnih mjesta u ruralnim područjima koja se u većini slučajeva nalaze u siromašnijim dijelovima Hrvatske.
5. Budući da je EU postavila ambiciozne ciljeve o određenim količinama biomase i biogoriva u potrošnji, pretpostavka je da će uvođenje *Miscanthus x giganteus*-a u intenzivniju proizvodnju pridonijeti ostvarivanju tih ciljeva, ne ugrožavajući primarnu djelatnost poljoprivrede odnosno proizvodnju hrane.
6. Prva veća preliminarna istraživanja u Hrvatskoj pokazala su zadovoljavajuće rezultate u uvođenju *Miscanthus x giganteus* u uzgoj. *Miscanthus x giganteus* se unatoč velikoj suši uspješno razvio na većini lokacija (do fenofaze metličanja) te se očekuje uspješno prezimljavanje prve zime kao najkritičnijeg razdoblja u zasnivanju dugotrajnog usjeva.

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MISCHANTUS X GIGANTEUS AS ENERGY CROP

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SUMMARY

Miscanthus x giganteus *hybrid, from the grass family (*Poaceae*) has been shown as an interesting and highly valuable variety for the renewable energy production from agriculture. According to the first major research,* Miscanthus x giganteus *hybrid can grow on poor and soils with lower quality in the Republic of Croatia, so he would not compete with food production as biomass for renewable energy sources. Today, according to the Statistical Yearbook (2010), over 600 000 ha of agricultural land is lower quality, even more this agricultural land began to convert into the unusable bush. This culture would facilitate the utilization of these agricultural areas. The advantages of* Miscanthus x giganteus *grass production are high yields and low requirements for fertilizer and almost no need for pesticides, which further contributes to the environmental sustainability in agricultural production and subsequent production of green electric energy. However, the fact that the crop remains on the field at least for 15 years, it is extremely important to conduct expertly and quality all of the agro-technical measures. In the Republic of Croatia, the first major study (11 sites) on the introduction of* Miscanthus x giganteus *started in the Faculty of Agriculture in Zagreb in 2011 year.*

Key worlds*: renewable energy, biomass, Miscanthus x giganteus*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Preliminary communication

MECHANICAL CHARACTERISTICS OF MISCANTHUS STALKS OBTAINED BY COMPRESSION TESTS

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SUMMARY

Mechanical properties of vegetable plants like straws, corn stalks, hay, peas and beans spindle, alfalfa are necessary to be known when we must choose an optimum apparatus for cutting and grinding plants and also the optimum working process of it. In this paper are presented the results of some experimental research regarding some mechanical properties (plants length, the samples average diameter) of the energetic plant Miscanthus gained by subjecting the plant to repeated compression tests obtained from the force-deformation curve showed by the Hounsfield mechanical testing apparatus. Determinations were done on samples from the internodes sections with the height of 30 mm and with a diameter in the range φ 4.26 – 8.91 mm. From the processing of the force-deformation curves gathered with the help of Qmat program, we collected data regarding the force and deformation in the rupture point, crushing stress applied, contact area in the rupture point. We found that the break force of miscanthus stalks was about 104 – 233N for the internodes located on the base of the stalks and about 55 – 149 N for the upper internodes of plants stalk. Corresponsive, the plants deformation up to the point of rupture was between the limits of 0.9 – 1. mm for the lower internodes of plants and between the boarders of 1.0 – 1.2 mm for the upper internodes. The elasticity module for miscanthus stalks were determined to be between 69.3 – 218.8 Mpa for the ground internodes and between 25.1 – 122.3 Mpa for the plants upper internodes. Also we determined the compression strain of all the samples and based on the strain – stress curves we calculated the elasticity module of the energetic plant Miscanthus. Energetic plant mechanical behaviour characterization is necessary for specialists in their line of work from equipment designers to exploitation specialists because they need to know proper parameters in order to make the design.

Key words: *miscanthus, mechanical characteristics, compression tests, force-deformation curve, elasticity module, break force, relative deformation, liniar regression*

INTRODUCTION

Biomass, the new source of renewable energy, gradually substitutes wood, as an alternative energy source, due to a high production of vegetable matter. [3, 5, 11]

A series of energetic plants are used today as renewable energy, such as energetic willow, energetic grass, rape, rice, wheat, miscanthus, etc. Out of these, miscanthus is the newest energy source in our country. According to studies [13], miscanthus has a dry material production between the range of 18 – 25 t/ha at a height of 3.5 m per season. In order for the vegetable material to be used by final consumers, a preparation process is necessary. This is the sum of operation such as: cutting, grinding, and briquetting. Inside the equipment used for these operations, a series of complex mechanical forces take place: crushing, shearing, bending, torsion, slip cutting, etc. For bio-energy production, high volume mass is an impediment and thus it goes though the process of briquetting. [7].

All these preparation processes are influenced greatly by the plant's mechanical properties and the way they interact in the frame of technological operations.

According to the technological process to which he material and its microstructure are subjected to, it can be determined the material characteristics of importance for this process [7]. During the process of preparation of miscanthus stalks, especially during compression stage, biomass can necessitate higher moisture content, thus water addition is necessary. According to recent studies [4], the humidity content must be of approximately 14.9 or even better 15%, the temperature of 115^{o}C, pressure of 32.99 MPa, in order to gain an optimum compression process. This operation is used for briquetting processes, because biomass must have small dimensions in order to be used in small household heating systems.

Through repeated solicitations applied to some miscanthus stalks, the vegetable material is broken. As the forces get higher, eventually the plant will break. The resistance structure of the plants is different when applying the forces, due to humidity content, which differs from plant to plant, this parameter being of great importance when energy consumption is tested during the process of plant preparation.

During the process of energetic plant preparation, disregarding the type of operation, material compression takes place right from the plant harvesting. In order to determine miscanthus behavior at mechanical load or compression strength of compression and the mechanical characteristics of the plant, this paper presents results of some experimental determinations, for this purpose.

MATERIAL AND METHODS

Stalk material used during experimentation were taken from the fields of the Bucharest National Institute of Research – Developing of Equipment and Installations destined for Agriculture and Foods Industry, March 2010. Miscanthus crop is in its third year, its first year being 2008. A well developed stalk was picked, with 14 internodes, 2.20 m height, mass of 18 grams and average base diameter of 7.78mm. Material samples subjected to compression tests were of approximately 30 mm in length, cut as two, four out of each intermodal area.

General moisture content of the harvested plants (the same for all stalks) was of 8.8 – 9.0%. Stalk calculated volume, approximating its shape with that of a conoid, disregarding the nod influence, was of 62.04 cm^3. At a first estimation, plant material density is of 0.3 g/cm^3. The samples used during the tests were weighted with an electronic balance Kern RH 120-3 with a measuring precision of 10^{-3} g, samples were also measured to determine its length and diameter, and the apparatus used being a calliper with 10^{-2} mm precision.

The equipment used during experimentation was a mechanical testing apparatus Hounsfield type, presented in papers [8, 9], having a software programme of data acquisition Qmat and a steel adaptor with the diameter of 34mm and a thickness of 8mm, connected to a charging cell of 1000N.

The crushing device travel speed was established so it wouldn't influence significantly the results of the experimental determinations, according to other information presented by authors in published scientific papers [6,10,12]. In our paper the crushing speed was established at 5mm/s.

The average diameter of each sample was determined, measured in two perpendicular plans at their middle. During experimental testing, deformation-force curves were drawn, from the analysis that could estimate the main mechanical characteristics of miscanthus stalks: deformation and bioyield point forces, respectively rupture, the energy required to reach those points. Knowing the relative deformation, and the rupture point of the sample, relative deformation and contact surface with the compression plates were determined, such as compression tension at rupture point. For a better analysis and result interpretation of the results out of the total tests, only the samples that had the possibility of reading the exact deformation, respectively force, in the rupture bio-flow points.

In order to determine the elasticity module, a calculus scheme was used from figure 1 that was tested for each of the 32 samples retained. Working methods were the same as the authors of papers [1]. In the upper side of the deformation-force curve, an inflexion point Pi was identified, after which on a broader area, the linear regression analysis was estimated, so that the inflexion point was a point from the regression line.

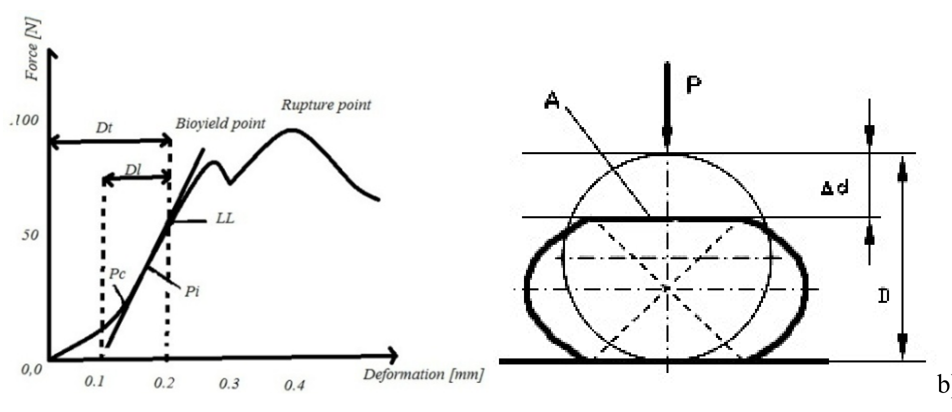

Fig. 1 a) Force –deformation curve [1], b) Transversal strain of miscanthus stalks

After that, all the elements for estimating the calculus point PC (see 1.a figure) were determined, for which the deformation and compression force were determined. Knowing the force and contact section area in the calculus point Pc, the normal compression tension was calculated, for this point, in order to determine the elasticity module (of the miscanthus stalk).

The equations used for determining compression tension, relative deformation and the elasticity module were:

$$\sigma = F / A \tag{1}$$

$$\varepsilon = \frac{\Delta d}{D} \tag{2}$$

$$E = \tan\alpha = \frac{\sigma}{\varepsilon} \tag{3}$$

in which: ε is the relative stalk deformation under loads; σ – compression stress; E – elasticity module [N/m^2]; D – average diameter [mm]; Δd – absolute strain [mm].

RESULTS AND DISCUSSION

Miscanthus samples used for the testing were of 30 mm in dimension and with a diameter in the range φ 4.26 – 8.91 mm. Dimensional characteristics of material samples: average diameter, length, mass, as well as the ones obtained from force-deformation curves are presented in Table 1.

Some of the force-deformation curves, together with the regression line in order to determine the calculus point Pc, necessary to estimate the elasticity module are presented in figure 2. From data analysis presented in table 1, it was discovered, that the stalk rupture force is between the limits of 104 – 233.3 N, for the first three internodes at the base of the stalk and in the limits of 54.75-149N for the internodes in the upper parts of miscanthus stalks.

According to these forces, plant deformation until rupture is between the limits of 0.908 – 1.64 mm, for the internodes from the lower part of the plant and in the limits of 0.96 – 1.19 mm for the internodes in the upper part of the plant.

From the force-deformation curves, obtained from Qmat program we established that at all samples, a growing ascent of the curve, relatively proportional of deformation with compression force, even if not all the samples had it relatively linear.

Table 1 Miscanthus sample physical characteristics and experimental date obtained

Inter-node	Length [mm]	Average diameter [mm]	Weight [g]	Break force [N]	Deformation at break, [mm]	Calculation force, [N]	Absolute strain [10^{-3} m]	Relative deformation [10^{-3} m]	Contact area [10-6·m]	Compression stress [Pa]	Elasticity module, [MPa]
1	29.04	8.43	0.499	176.8	0.908	91.20	0.596	0.07	6.2	14.65	207.16
	29.81	8.25	0.413	199.3	1.114	90.75	0.684	0.08	6.6	13.80	166.39
	29.25	7.90	0.373	233.3	1.140	121.25	0.792	0.10	6.9	17.58	175.4
	30.50	7.73	0.363	117	1.070	53.10	0.673	0.09	6.3	8.42	96.67
2	30.71	8.09	0.442	193.6	0.935	86.00	0.596	0.07	6.1	14.11	191.52
	30.93	7.60	0.358	203.3	0.990	118.00	0.661	0.09	6.2	19.03	218.82
	30.00	7.11	0.324	173.4	1.640	53.60	0.741	0.10	6.3	8.48	81.37
3	28.91	7.29	0.284	126.8	1.605	35.10	0.625	0.09	5.9	5.94	69.31
	30.05	6.87	0.278	109.1	1.216	33.50	0.577	0.08	5.5	6.08	72.37
	31.31	7.24	0.318	104	1.592	47.125	0.700	0.10	6.2	7.59	78.47
	29.36	6.89	0.253	110.3	1.327	27.25	0.593	0.09	5.6	4.87	56.61
4	29.35	6.61	0.26	99.5	1.165	37.38	0.491	0.07	5.0	7.48	100.63
	29.10	6.48	0.229	168.6	0.662	79.37	0.444	0.07	4.7	16.83	245.69
	29.69	6.11	0.208	59.64	0.904	27.78	0.756	0.12	5.9	5.90	47.69
	29.12	6.33	0.224	75	0.621	34.74	0.412	0.07	4.5	5.45	83.72
5	30.41	6.22	0.196	53.31	0.669	24.48	0.498	0.08	4.9	8.89	111.08
	30.62	6.16	0.199	80.13	0.737	43.38	0.425	0.07	4.5	3.70	53.67
6	28.51	6.11	0.141	49.43	0.915	16.65	0.557	0.09	5.1	5.84	64.02
	29.63	5.95	0.148	111	1.140	29.75	0.784	0.13	5.99	5.03	38.18
	29.94	5.99	0.151	56.11	0.840	29.70	0.727	0.12	5.7	3.32	27.32
7	28.3	5.95	0.123	69.15	1.232	18.97	0.584	0.10	5.1	8.79	89.57
	30.41	5.84	0.131	82.5	0.907	45.20	0.571	0.10	5.0	5.94	60.71
8.	29.35	5.27	0.103	70.4	0.960	29.90	0.504	0.10	4.5	11.70	122.33
	30.75	5.46	0.111	111.8	1.234	52.63	0.797	0.15	5.7	7.50	51.37
9	29.3	5.29	0.109	76.7	1.164	42.60	0.884	0.17	5.9	5.46	32.65
	29.98	5.20	0.117	69.3	1.204	31.95	0.728	0.14	5.3	3.86	27.56
	29.82	4.62	0.083	61.5	1.156	20.48	0.606	0.13	4.6	3.77	28.75
	29.77	4.49	0.076	54.75	1.082	17.25	0.568	0.13	4.4	13.86	109.58
10	29.00	4.54	0.074	149	1.371	60.60	0.801	0.18	5.2	9.55	54.14
	28.89	4.56	0.074	108.9	1.284	49.20	0.726	0.16	4.9	12.10	76.01
	28.99	4.61	0.076	108.6	1.186	59.75	0.865	0.19	5.4	5.78	30.83
	29.03	4.61	0.082	80.5	1.118	31.10	0.648	0.14	4.7	3.53	25.13

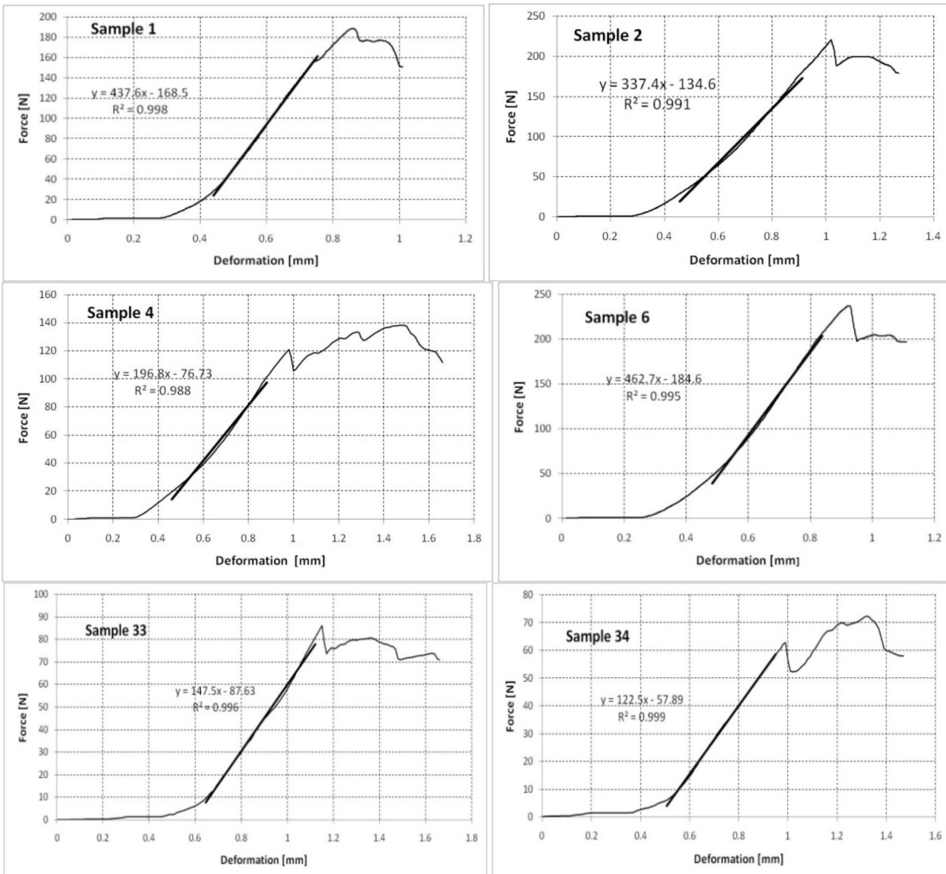

Fig. 2 Force – deformation curve resulted during compression tests for some samples

The analysis of force -deformation curves (see fig.2) show the existence of bioyield point (for biological materials) and of rupture point, but not all drawn curves for the analyzed samples have a bioyield point. Also, as it can be seen in figure 2, experimental points from the growing force- deformation curve present a high correlation degree ($R^2 \geq 0.988$) with linear distribution law (obtained from regression analysis), which expresses the correct appreciation of the calculus point, necessary o estimate the elasticity module of the miscanthus plant on a relatively growing area of the curve. The coefficients of the linear regression equation and the values of the correlation coefficient R^2 for analyzed samples are presented in table 2.

The values of compression force, absolute deformation, respectively relative, of the material in Pc calculus point, determined after the ladder procedure are presented in the same table. It is concluded that the compression force values in the point of calculus presents a high spread that shows lack of uniformity in the mechanical characteristics of miscanthus stalk, not only for different internodes, but in the same interned as well, due to a multitude of influence factors (culture conditions, humidity, bark thickness, diameter of the core, etc.), but possibly it is also due to conservation conditions or cutting conditions.

Table 2 Linear regression equation coefficients (y = a·x+b) and the correlation coefficient R^2 for analyzed samples

Sample no.	A	b	R^2	Sample no.	A	b	R^2
1	437.6	168.5	0.998	18	63.42	18.49	0.997
2	337.4	134.4	0.991	21	156.7	91.58	0.975
3	333.5	142.4	0.998	22	119.6	54.51	0.981
4	196.8	76.73	0.988	24	84.41	29.03	0.985
5	503.1	210.1	0.992	25	168.9	52.02	0.998
6	462.7	184.6	0.995	26	148.8	45.35	0.998
7	178.2	77.01	0.996	31	145.1	61.22	0.995
9	126.2	42.50	0.996	32	147.5	87.63	0.996
10	148.9	50.15	0.991	33	122.5	54.89	0.999
11	106.1	25.50	0.996	34	95.32	36.45	0.995
12	136.4	52.66	0.995	35	88.20	32.01	0.991
13	174.3	48.32	0.997	36	204.8	98.37	0.99
14	630.2	203.3	0.995	37	174.3	72.7	0.989
15	260	72.26	0.998	38	196	110.8	0.997
16	145.9	47.14	0.993	39	132.2	51.54	0.985
17	280.7	77.31	0.996	40	180.7	103	0.991

From the vast array of values presented for rupture forces, at the point of bioyield, respectively at rupture point, it must be considered that the majority of values and especially the high value ones can lead to a correct appreciation of the power and energy necessary for plant cutting, respectively its deformation.

Values of sample contact section area with the two compression plates (inferior – fixed, superior- loose), calculated on the basis of initial dimensions, respectively after sample deformation, are presented, as well in table 1. Applying the relation (1), values of compression tension were calculated, after which we applied relation (3) and calculated the values of elasticity module, presented, as well, in table 1.

Data analysis from table 1 shows an arbitrary dispersion both for compression tension values, as well as for the elasticity module. However, as it can be seen, the values of the elasticity module, for the internodes from the lower part of the plant are between the limits 69.31 – 218.82 MPa, while the elasticity module values for the internodes from the upper part are between the limits of 25.13 – 122.33 MPa.

Spreading degree and the correlation between the elasticity module and the sample average diameter, its mass, the force in the calculus point and the compression tension, for each point are presented in figure 3.

After establishing the regression analysis of experimental data with the linear repartition law, we obtained a correlation degree relatively high ($R^2 \geq 0.857$), for the interdependency relation between the elasticity module and force, respectively compression tension, in the calculus point Pc.

For elasticity module correlation with the average diameter, sample mass, correlation coefficient R^2 had relatively low values ($R^2 \geq 0.507$) which expresses, as it has been shown, the non-uniformity of mechanical characteristics of miscanthus stalks in mono-axial compression tests.

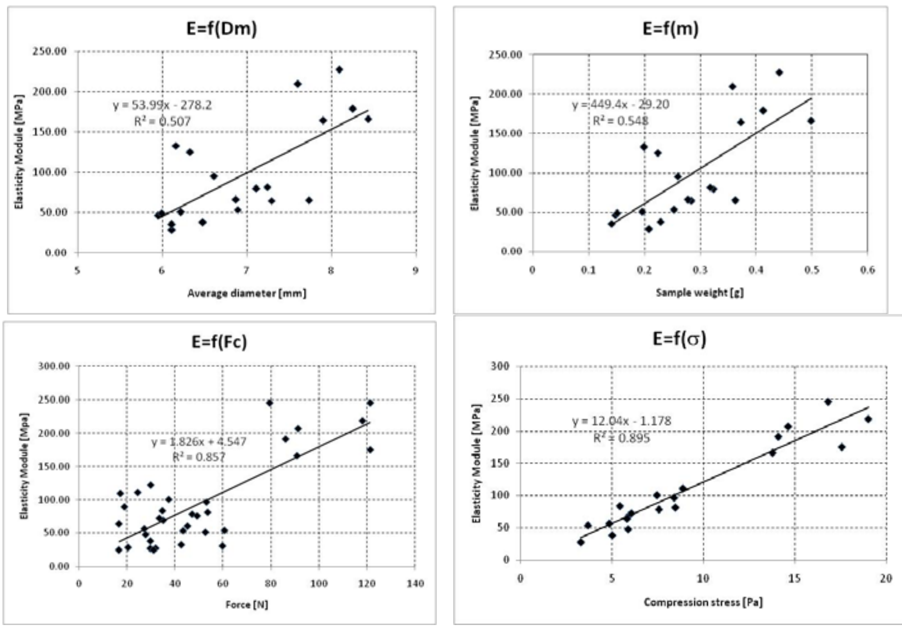

Fig. 3 The correlation of the elasticity module with the average diameter (a), the sample weight (b), the compression force (c) and the compression stress (d).

From the analysis of obtained data, we can estimate, though, the average value of elasticity module, respectively of the tension of compression for miscanthus plants, subjected to deformations, respectively to mechanical preparation.

CONCLUSIONS

Mechanical behaviour of miscanthus plants at compression tests, mono-axial, have shown non-uniformity of mechanical characteristics obtained, from force-deformation curves. The average value of stalk relative deformation for the point in which the force for estimating the elasticity module was determined, presents smaller values in the lower part of the plant (approximately 0.09 mm) and higher values in the upper part (approximately 0.15 mm). In comparison, the average elasticity module had higher values in the lower part of the plant (129 MPa) and lower values for the upper part (56 MPa), the same thing being seen for the compression tension.

From the data presented in this paper it can be concluded that it is possible to make assessments regarding the miscanthus stalk stiffness using the parameters obtained from the force – deformation curves resulted through uniaxial compression tests. These parameters are the deformation at break point, deformation at linear limit, but mostly the elasticity module of the plant.

The statistical analysis of the elasticity module data for the miscanthus stalks exhibits a relative scatter of this values in correlation with the average diameter of stalks, samples weight, force and compression stress at the linear limit.

However, the correlation with the linear distribution of the presented parameters displays appropriate values, especially for the correlation between the elasticity module with the force and compression stress.

The values of miscanthus stalks mechanical characteristics are useful for experts in the field of design of miscanthus processing technology and machinery.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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NON-FOOD PRODUCTION OF JERUSALEM ARTICHOKE (*HELIANTHUS TUBEROSUS*) AND POSSIBILITIES OF ITS ENERGETIC UTILIZATION

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SUMMARY

Jerusalem artichoke (Helianthus tuberosus) is a not widely grown crop. It is universally usable, in human diet (source of inulin), for livestock feeding and as an energy crop. In field trials performed in Valecov Research Station belonging to PRI Havlickuv Brod, during 2008 – 2010 an effect of genotype and growing technology was studied on Jerusalem artichoke production characteristics. Totally, 13 clones were used. The harvest of aboveground mass was done in autumn, tubers were harvested in spring (though deep soil freezing, the tubers are not frost-killed). In dependence on year and clone, yields of aboveground part reached 34,2 – 71,9 t FW/ha (12,4 – 24,7 t DW/ha). The yield of spring-harvested tubers ranged between 21,8 and 38,3 t/ha (4,4 – 7,9 t DW/ha). Growing technologies for Jerusalem artichoke were verified, in relation to optimization of cultural practices for obtaining high yields. The most effective fertilization variant was 100 kg N/ha and foliar application of urea, between planting densities no significant differences were recorded for yields. The trials were established to determine soil conservation and ecological function of Jerusalem artichoke crop. On two dates intensive rainfall was simulated on Jerusalem artichoke crop grown on slope. On the first date (July) reduced water runoff and a half soil loss (0,405 t/ha) were found compared to potato crop (0,84 t/ha). On the second date (September), when potato crop is already lodged, the more favourable situation was determined in potatoes compared to Jerusalem artichoke crop. Biogas recovery of aboveground part was studied in two clones, differing in production of aboveground biomass and stem: leaf ratio. Biogas recovery in the sample A was 103 – 110 m^3/t FW, corresponding to methan recovery 68 – 70 m^3/t FW. Biogas recovery in the sample B was 69 – 84 m^3/t FW, corresponding to methan recovery of 41,8 – 54,5 m^3/t FW.

The results of trials indicated relatively high potential of Jerusalem artichoke in regard to possibilities for non-food use.

Key words: *Jerusalem artichoke, genotypes, growing technology, bioenergy*

INTRODUCTION

Jerusalem artichoke is a not widely grown crop, originating in Northern America. Into Europe it was introduced in the 16th century from Mexico. It is universally usable - in human diet (source of inulin), livestock feeding and as an energy crop. Naturally, the most scientific studies are focused on use of Jerusalem artichoke for food purposes. The reason is the most appreciated characteristic of Jerusalem artichoke – content of inulin.

Inulin is an oligosaccharide or polysaccharide, which replaces starch as a storage substance in plants from family Asteraceae and Campanulaceae. Inulin is a valuable substance especially for diabetics. It is not splitted in small intestine, it is not resorbed and used. It is caloric value is very low to nil; it does not increase blood sugar level. Inulin is sweet, therefore it could replace sugar or fat (in low-fat products).

Varieties/clones of Jerusalem artichoke are not a strong centre of research interest in Europe. It is mainly caused by the fact that Jerusalem artichoke varieties are not officially mentioned in Common Catalogue of Varieties of Agricultural Plants. Under the Asian conditions varieties with differing responses to drought stress are known (Xiuyan, Yulin), as referred by Zhang et al. (2011). Gao et al. (2011) studied the effect of irrigation and nitrogen fertilization on biomass yield of Jerusalem artichoke aboveground and underground parts.

They were also focused on relations between roots, stems, tubers and leaves. Significant differences were only found under irrigation. In the Czech Republic research studies concerning Jerusalem artichoke have a tradition. At first, Votoupal (1986) and later Cepl et al. (1997) were more extensively aimed at Jerusalem artichoke study. Nowadays studies in PRI are focused on energy and feed use of the crop. Jerusalem artichoke is highlighted as s prospective energy crop for sustainable bioethanol production (Matias et al., 2011). It has a high yield and carbohydrate content, at present; its energy use does not interfere with the food chain. However, the main storage carbohydrate of Jerusalem artichoke, inulin, cannot be directly fermented by classical fermentation, it is necessary to use yeasts with inulinase activity to recover bioethanol. For this reason total sugar content, but also sugar composition must be known for optimization of bioethanol production from Jerusalem artichoke tubers. Smolinsky et al. (2011) compared energy crops, such as *Spartina pectinata*, *Helianthus tuberosus* L., *Sida hermaphrodita* R. and *Miscanthus giganteus* with hard coal in an experimental study. The ability of hard coal and biomass to undergo thermochemical transformation was determined based on their features of reactivity. Tested biomass samples were relatively more reactive, but produced less synthesis gas and had a lower calorific value. Lelio et al. (2009) refer that *Helianthus tuberosus* L. is a potential suitable crop for production of bioethanol added to fuel. Several studies indicate that 4500 l ethanol could be produced from 50 tonnes of tubers. The authors compared yield of two varieties and two types of irrigation. Tuber yield showed differences in irrigation. For production of 1 l ethanol 11 kg of tubers were required, under precondition of 16 % tuber dry matter.

METHODS

Study of clone and growing technology effect on yielding parameters of Jerusalem artichoke

Exact field trials were established in Valecov Research Station belonging to PRI Havlickuv Brod. The station is situated in the potato production region. The station is characterized by mildly gleyed cambizem, 460 m altitude, 6,99 °C annual mean temperature, 13,20 °C mean temperature during vegetation, 652 mm annual mean rainfall and 425 mm rainfall during vegetation.

For a clone trial plot was sized 2,25 x 7,0 m = 15,75 $m^{2,}$ i.e. 3 rows containing 20 hills each = 60 hills. The trial was established in randomized complete block design. There were used 4 replications (a-d).

Manual planting of the trial was performed into ridges in spring (April) of given year. Based on the variants, trial crops were manually fertilized prior to planting and foliar application of urea solution was done during vegetation. Basic nutrient rate was 100 kg N, 120 kg K2O and 40 kg MgO/ha. In the variant with increased N rate fertilization was done into required level. After planting weeds were uniformly controlled, with pre-emergent application of 1 l Afalon 45 SC (linuron). Subsequently, the crops were not treated by any pesticides.

The harvest of aboveground plant part was done by manual foliage cutting in harvest and tubers were harvested in spring of following year using of one-row potato planter Samro SCA.

Harvested material from each plot was weighed and a 15-kg sample was taken for further analysis (food and feed utilization).

Variants of used clones (Source: the clone collection managed by PRI H. Brod): Běloslupká, Reka, Refla, K 24, C 63, Karina, Urodny, Völken. Spindel, Lola and Gigant.

Growing technology (2008 – 2010):

Variant	N fertilization (kg /ha)		Planting density (mm)
	Pre-planting	In vegetation	
1	100	0	750x350
2	100	0	750x700
3	200	0	750x350
4	200	0	750x700
5	100	36	750x350
6	100	36	750x700

Determination of soil conservation effect of Jerusalem artichoke crop

In 2010 erosion control, soil conservation function of Jerusalem artichoke crop was studied. Using rainfall simulator surface water runoff and soil loss were measured.

Jerusalem artichoke, potato and oat crops were compared. Plots of these crops were established on a sloping field. The slope size was 5°.

Measurements were done on two dates. The first was done on the 29th July 2010. The height of Jerusalem artichoke, potato and oat plants was 100, 45 (crop cover was complete) and 85 cm, respectively. On the second date (the 7th September 2010) only Jerusalem artichoke and potatoes were present on the plot. Jerusalem artichoke height was 200 cm, potato foliage was already lodged on this date.

The measurement was always done twice, for the first time rain was simulated to dry soil, for the second time the soil was already wet.

Rainfall amount and rainfall intensity was measured and beginning of surface water runoff was determined from the beginning of rain simulation, surface runoff was measured in mm and l, water infiltration and soil loss.

Tests of biogas production from Jerusalem artichoke foliage of two selected varieties

Tests were done in cooperation with Institute of Chemical Technology, Prague (ICT). Two clones were evaluated – C 63 (A) and Karina (B). These two varieties are contrasting in production of aboveground mass and stem: leaf ratio. Sampling was done on the 31st August 2010.

Sample treatment

Supplied samples were weighed and divided into two parts – leaves and stalks and weighed. Each part was cut into approx. 2 – 5 mm and mixed in original weight proportions. Two mixed samples were formed designated as MixA, MixB.

The sample A was characterized by very hard stalks and flower presence. The sample B contained much more thick stalks.

Tests of biogas production were done with mixed samples MixA and MixB, with each under two inoculum loads (anaerobically stabilized sediment).

RESULTS

The results are given in Tables 1 – 7.

For statistical assessment of the results one-way ANOVA with following Tukey's HSD test was used. The highest statistical significant yielding level was recorded for clones Völken Spindel and Urodny. In relation to requirements for tuber biomass production we can recommend these clones as clones with highest production.

The year effect was expressed as highly statistical significant in all studied years. Lower yielding level of the harvest 2009/2010 was caused by unfavourable weather conditions in the spring 2009. Delayed onset or spring substantially inhibited spring works and planting was shifted to the 20th May. On this date tubers were already highly chitted and partially damaged, so emerged sprouts had to be removed in all seed potatoes. Crop emergence was delayed and very uneven. The lowest yielding level was recorded for the harvest 2010/2011. In this year more than 100 % differences in yields were found among clones (C63 17,0 t/ha, Urodny 39,1 t/ha). The reason was strong alternation of drought stress and water excess. It indicates variety sensitivity/tolerance to drought and it is confirmed by Zhang et al. (2011), who found drought sensitivity in two varieties Xiuyan and Yulin.

Table 1 Clone effect on Jerusalem artichoke yielding indicators – tubers (2008/2009 – 2010/2011)

Clone	Tuber yield		
	2008/2009	2009/2010	2010/2011
	t/ha	t/ha	t/ha
Běloslupká	57,74 a	28,53 cd	31,13 ab
Reka	56,02 a	23,48 d	19,05 bc
Refla	55,81 a	21,79 d	21,99 bc
K 24	59,10 a	37,36 ab	20,07 bc
C 63	44,91 a	33,83 abc	17,01 c
Karina	53,98 a	38,09 a	24,83 bc
Urodny	48,76 a	38,27 a	39,07 a
Völken. Spindel	61,67 a	36,17 abc	29,88 ab
Lola	53,50 a	29,24 bcd	22,96 bc
Gigant	51,60 a	36,39 abc	27,52 abc
Statistical year effect			
Mean of clones	54,31 a	32,32 b	25,35 c

Table 2 Clone effect on Jerusalem artichoke yielding indicators – aboveground part (2008)

Clone	Yield of aboveground part	
	original mass	DW
	t/ha	t/ha
Běloslupká	34,67	14,37
Reka	42,33	14,43
Refla	54,52	21,41
K 24	57,38	19,38
C 63	33,91	12,44
Karina	71,52	23,27
Urodny	14,24	7,66
Völken. Spindel	56,29	22,47
Lola	62,86	24,76
Gigant	35,48	12,93
Mean of clones	46,32	17,31

Weight of aboveground part was highest in clone Karina, followed by Lola and K 24, from this regard the clones could be recommended for energy use.

Table 3 Growing technology effect (N fertilization and planting density) on Jerusalem artichoke yielding indicators

	2008	2009	2010	Mean of years
Variant	t/ha	t/ha	t/ha	t/ha
1	62,22	34,83	18,86	38,64
2	48,92	27,55	13,99	30,15
3	62,14	33,16	17,86	37,72
4	52,83	29,87	11,24	31,31
5	64,00	35,71	19,51	39,74
6	50,18	31,52	15,15	32,28
Mean of variants	56,71	32,11	16,10	34,97

Statistical assessment of factors			
Harvest years	2008/09	2009/10	2010/11
N rate tuber yield (t/ha)			
100 kg/ha	55,57 a	31,19 a	16,43 a
200 kg/ha	57,49 a	31,52 a	14,55 a
Planting distance tuber yield (t/ha)			
750x350	62,79 a	34,57 a	18,74 a
750x700	50,64 b	29,65 a	13,46 b

Studied N rates had no effect on tuber yield. The rate 100 kg N/ha was expressed as sufficient, for double rate (200 kg N/ha) any effects were not recorded, similarly as foliar N application during vegetation (var. 5 and 6). It partially corresponds to Gao et al. (2011), who found substantial influence of N fertilization on plant height and yield; however, only under irrigation conditions. Their results showed that water was the main limiting factor.

Tighter planting density (750 x 350 mm, i.e. 38 092 plants/ha) brought high statistical significant higher tuber yield in the harvest 2008/09 and 2010/11 (statistical assessment was done using two-sample test of means). Although for smaller planting density (750 x 700 mm, i.e. 19 047 plants/ha) we can calculate with half cost of seed tubers, this yield difference outperforms the saving.

However, these problems have not been studied by any other authors yet. Considering further cultural practices increasing biomass production we can use e.g. mycorrhizal inoculation associated with organic matter supply (Puschel et al. 2011).

Table 4 Results of measuring soil loss and surface water runoff using field rain simulator in studied variants in Valečov (2010, the 29th July)

Crop	Soil state	Crop height (cm)	Rainfall duration (min)	Rainfall amount (mm)	Soil loss	
					($g.m^{-2}$)	($t.ha^{-1}$)
Jerusalem artichoke	Dry	100	15	13,17	40,5	0,405
	Wet			13,68	61,5	0,615
Potatoes	Dry	45	15	13,58	83,7	0,837
	Wet			13,66	131	1,310
Oat	Dry	85	15	13,61	0,039	0,001
	Wet			13,58	0,7	0,007

Table 5 Results of measuring soil loss and surface water runoff using field rain simulator in studied variants in Valečov (2010, the 7th September)

Crop	Soil state	Crop height (cm)	Rainfall duration (min)	Rainfall amount (mm)	Soil loss	
					($g.m^{-2}$)	($t.ha^{-1}$)
Jerusalem artichoke	Dry	200	15	13,53	161,2	1,612
	Wet			13,62	171,7	1,717
Potatoes	Dry	45	15	13,62	85,4	0,854
	Wet			13,59	20,9	0,209

On the first date (the 29th July) reduced water runoff and half soil loss (0,405 t/ha) was found in Jerusalem artichoke crop compared to potato crop (0,837 t/ha). On the second date, when potato foliage was already lodged, the more favourable situation was recorded for potatoes compared to Jerusalem artichoke crop. The reason was lodged potato foliage on the bottom of furrows, which slowed down water runoff and hindered soil loss. Study of soil conservation effect of various crops on slope fields is important in relation to regulations of Good Agricultural and Environmental Conditions (GAEC2) valid in the Czech Republic and this is ground for subsidy allocation http://marswiki.jrc.ec.europa.eu/wikicap/index.php/Good_Agricultural_and_Environmental_Conditions_(GAEC).

Jerusalem artichoke seems to be a suitable crop from this regard, since it provides crop cover also during winter.

Evaluation of biogas recovery

The results of tests of biogas recovery indicated the good anaerobic degradability of Jerusalem artichoke plant mass. Summary results of performed tests are given in Tables 6 and 7.

Table 6 Resulting values of specific biogas production

	MixA 0,3	MixA 0,5	MixB 0,3	MixB 0,5
Specific biogas production				
ml/g CHSK	382,94	358,15	387,15	318,21
ml/g DW	658,44	615,82	693,55	570,06
ml/g sample	110,29	103,15	83,62	68,73

Table 7 Evaluation of methan production

	MixA 0,3	MixA 0,5	MixB 0,3	MixB 0,5
Specific CH_4 production				
ml/g CHSK	245,65	231,63	252,38	193,84
ml/g DW	422,39	398,28	452,13	347,25
ml/g sample	70,75	66,71	54,52	41,87
CH4 in biogas [%]	64,15	64,67	65,19	60,91
CH4 production efficacy [%]	70,19	66,18	72,11	55,38

CHSK – organic substance content

The samples A and B slightly differed in dry matter content (167,5 and/or 120,6 g/kg sample) and also in organic substance content.

Biogas recovery in sample A is 103 – 110 m^3/t FW, corresponding to methan recovery 68 – 70 m^3/t FW containing 64 % methan in biogas (only small differences were expressed in trials with various loads).

Biogas recovery in sample B is 69 – 84 m^3/t FW, corresponding to methan recovery 41,8 – 54,5 m^3/t FW containing 60 – 65 % methan in biogas (lower values correspond to trials with increased load).

Above mentioned results confirm current opinions of many authors concerning suitability of using Jerusalem artichoke in relation to bioenergetics (Matias et al. 2011, Chi et al. 2011, Yang et al. 2011, Lim et al. 2011, Li et al. 2010). In two last years, most authors refer about use under conditions of China.

CONCLUSION

Among studied clones materials were found with high statistical significant improved yield (except for the harvest 2008/09). The clones were Völken Spindel and Urodny. Simultaneously, significant effect of year was found given by weather conditions.

Within the studied elements of growing technology N fertilization had no significant effect on yielding level and we can recommend reduced N rate (100 kg/ha), which is more suitable in regard to environmental protection and production economy; on contrary, planting distance expressed as highly statistical significant and spacing 750 x 300 mm could be unambiguously recommended.

Greater soil conservation function of Jerusalem artichoke crop compared to potatoes was only expressed on the first evaluation date.

Results of biogas production from Jerusalem artichoke indicated that this crop could be regarded as potential source of bioenergy.

The results of Jerusalem artichoke study confirmed its important characteristics, for which this crop is rightly in the centre of interest of breeders and growers. This means high ability of biomass production, low demands for growing technology with maintaining good environmental conditions and in addition to known use in food industry (inulin) high potential in use in the field of bioenergetics.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631.453:633.853.492:665.334.9
Prethodn o priopćenje
Preliminary communication

MOŽNOSTI UPORABE OLJNE OGRŠČICE IZ ZEMLJIŠČ ONESNAŽENIH S TEŽKIMI KOVINAMI ZA ENERGETSKE IN DRUGE NAMENE

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IZVLEČEK

*V prispevku proučujemo možnost remediacije s težkimi kovinami onesnaženih tal s pridelavo oljne ogrščice za energetske in druge namene. Opravili smo mehansko ekstrakcije semena oljne ogrščice (*Brassica napus *L.* var. napus*) z mehanskim stiskanjem s stiskalnico kontinuiranega tipa po dvofaznem postopku. Ugotavljali smo porabo energije za stiskanje semena ter distribucijo težkih kovin v olju in pogači. Za raziskavo smo izbrali semena hibridov PR45 D01, PR46 W31 in PR45 D03 oljne ogrščice (*Brassica napus *L.* var. napus*), ki se v Sloveniji najpogosteje uporabljajo za pridelavo olja. Ugotovili smo da z naraščanjem vrtilne frekvence stiskalnega polža se specifična poraba energije povečuje, izplen olja pa zmanjšuje. S stališča energetske porabe in izplena olja je najbolje uporabljati čim nižje vrtilne frekvence. Večje kot so vsebnosti Pb in Cd v tleh, večje so vsebnosti Pb in Cd v rastlinskih delih (korenine, stebla in semena) in posledično tudi v pogači in v olju hladno iztisnjenih semen. Glede na slovensko zakonodajo dobljena olja iz hibridov PR45 D01 in PR46 W31 po I. in II. hladnem stiskanju semen prekoračujejo vsebnosti Pb v olju, kot živilu, zato je olje primerno samo za energetske namene.*

Ključne besede: *onesnaženost tal, težke kovine, remediacija tal, oljna ogrščica, mehanska ekstrakcija rastlinskega olja*

UVOD

Onesnaženost tal s težkimi kovinami zaradi onesnaževanja v preteklosti predstavlja velik ekološki in gospodarski problem v večini držav EU in tudi v Sloveniji (Kos in Leštan, 2003). V prevelikih koncentracijah predstavljajo resno grožnjo za zdravje ljudi in živali. Remediacijo onesnaženih tal lahko izvajamo na biološki, fizikalno-kemijski ali termični način (Leštan s sod., 1997). Poteka lahko in-situ, na mestu onesnaženja, ali ex-situ, onesnažena tla izkopljemo in začnemo s postopki čiščenja. Uporaba tehnologije remediacije je odvisna od onesnaženosti območja, ki ga želimo revitalizirati. Praviloma povečini vse tehnologije predstavljajo tehnični in finančno največji vložek, ki pa niso nujno vedno ekonomsko sprejemljive. V preteklosti so za eko remediacijo tal zagovarjali procese saniranja z odkopavanjem kontaminiranih plasti tal in razvažanjem omenjenih tal na druge lokacije. Omenjena metoda je energetsko, časovno in okoljsko sporna. Za odkopavanje je potrebno angažirati posebne stroje za izkop (gradbene, rudniške itn.) in odvoz materiala. Za pogon omenjenih strojev se uporablja energija fosilnih goriv, ki prispeva ustvarjanju emisij CO_2 in drugih toplogrednih plinov. Metoda zahteva ogromno časa, pri izkopu pa nastaja tudi prah, ki ga lahko veter raznaša in se kontaminirani prah lahko prenaša na velike razdalje. Poleg tega se problem onesnaženosti samo prenese z enega na drugo območje. Mehanske metode za obdelavo tal in situ so glede dostopnosti in ekonomike najbolj obetajoče v današnjem času. Za remediacijo tal onesnaženih s težkimi kovinami in drugimi snovmi, ki lahko onesnažijo tla je možno uporabiti veliko delovnih postopkov in strojev, ki se danes uporabljajo v kmetijski pridelavi.

Eden od ukrepov revitalizacije onesnaženega ozemlja s težkimi kovinami je pozelenitev z energetskimi rastlinami in situ, s katerim ne da samo da polepšamo izgled okolice, pač pa tudi omejimo zapraševanje težkih kovin v okolico. Izbira rastlin za remediacijo tal je povezana tudi s tehnologijami za njihovo pridelavo. V primeru uporabe rastlin za človeško in živalsko prehrano se pridelujejo tradicionalne rastline, ki so značilne za prehrano človeka in živali. Pridelava lahko poteka na minimalno onesnaženih zemljiščih s klasičnimi pridelovalnimi postopki oziroma obstaja tudi možnost redukcije števila delovnih operacij. V nekaterih primerih zadostujejo že enostavni in ekonomsko upravičeni ukrepi, kot je npr. globoka obdelava tal (pri minimalni kontaminaciji površinske plasti tal) ali obračanje horizontov tal, kjer je možno površinsko kontaminacijo spraviti v globlje plasti in na površini intaktnih tal gojiti rastline. Rastline, ki jih gojimo na srednje in zelo onesnaženih tleh, je možno uporabiti samo za energetske namene. V to skupino se uvrščajo rastline, ki so v osnovi tudi namenjene za človeško ali živalsko prehrano vendar se zaradi velike vsebnosti škodljivih snovi ne smejo uporabiti za prehrano. Možna je uporaba klasičnih in delovnih operacij in njihove redukcije, tako kot v prejšnjem primeru.

In situ fitekstrakcija je biološka metoda, ki je primerna na malo ali srednje onesnaženih tleh in je ekonomsko najbolj sprejemljiva metoda. Pri tem procesu izbrane rastline akumulirajo in koncentrirajo toksične kovine v koreninski sistem ter v nadzemni del (Ribarič in Grabner, 2007). Vsebnost kovin v rastlinah je posledica sprejema kovin iz tal in iz zraka (aerosoli, prašni delci,…) (Markert, 1993). Razporeditev elementov v rastlini je odvisna od njihove mobilnosti. Mobilni elementi so N, K, Mg, P, Cl, Na, Zn, Mo in Cd, nemobilni pa Ca, S, Fe, B, Cu in Pb (Taiz in Zieger, 2002). Vsebnosti nemobilnih elementov v starejših listih naraščajo, lahko pa se zadržujejo v visokih koncentracijah v koreninah kot npr. Pb (Ernst s sod., 1992), medtem ko lahko rastlina mobilne elemente premešča glede na potrebe. Rastline lahko preprečujejo prehajanje kovin v rastlino ali pa jih akumulirajo v tkivih in z uporabo notranjih mehanizmov zmanjšajo škodljive vplive (Baker, 1981). Izključitev poteka na dveh ravneh: izključitev iz korenine ali izključitev iz nadzemnih delov. Najboljša strategija je seveda preprečiti vnos težke kovine v rastlino z izločanjem eksudatov, ki vežejo težke kovine in jih imobilizirajo. Akumulatorske rastline so odporne na kovine in imajo razvejan koreninski sistem (Brooks, 1998). Rastline se razlikujejo glede na to, kako tolerantne so na velike koncentracije težkih kovin. Rastline, ki lahko prenesejo velike koncentracije težkih kovin v njihovih nadzemnih delih, imenujemo hiperakumulatorji. Do sedaj so odkrili in preučili že več kot 400 vrst iz rodov Brassica, Alyssum, Arabidopis in Petrisis (Roosens s sod., 2003). Je pa potrebno poudariti, da je večina hiperakumulatorjev selektivnih za en element in niso uspešni na rastiščih z vsebnostjo več težkih kovin (Kamnev in Van der Lelie, 2000). Problem, ki se pojavlja je, da so hiperakumulatorji rastline, ki rastejo počasi in imajo majhen letni prirastek. Zato v svetu intenzivno poteka iskanje ustreznih hitreje rastočih rastlin-kandidatk za uporabo pri fitoremediaciji (Marchiol s sod, 2004). Ena od možnih kandidatk je tudi oljna ogrščica. Oljna ogrščica predstavlja z vsemi drugimi uporabnimi lastnostmi primerno rastlinsko vrsto za in situ fitoremediacijo težkih kovin predvsem na srednje ali malo onesnaženih območjih, kjer rast rastlin zaradi težkih kovin ni oslabljena (Grispen s sod., 2005; Marchiol s sod., 2004). Remediacija onesnažene zemlje je nujno potrebna za sonaravni in trajnostni razvoj kmetijskih površin. Tako ima oljna ogrščica (Brasica napus L. var. napus) po navedbah Kosa in Leštana fitoekstrakcijski potencial za Pb 0,15 kg/ha, za Zn 0,54 kg/ha in za Cd 0,012 kg/ha ob dodajanju EDDS, ki naj bi pospešila izločanje kompleksov težkih kovin skozi talni profil (Kos s sod., 2003). Teoretično je predvideno, da bi s koncentracijo 1 odstotka Pb v suhi rastlinski masi, priporočeno zmanjšanje koncentracije Pb v zemlji z začetne 1.100 do končne koncentracije 300 mg/kg Pb (omejitev po 86/278 EC) dosegli približno čez 10-15 let (Kos s sod., 2003). Za fitoremediacijo onesnaženih tal se uporabljajo hitro rastoče rastline (Wittig, 1993), ki so toksitolerantne in jih uporabljajo na onesnaženih območjih v središčih mest, industrijskih področjih (Kovacs s sod.,1993) in ob cestah (Öztürk in Türkan, 1993).

Snovna in energijska izraba oljne ogrščice (med, jedilno olje, tehnično olje, biodizel, podorina kot zeleno gnojilo in biomasa) je odvisna od vsebnosti kovin v njenih delih. Slovenska zakonodaja, Uredba o mejnih, opozorilnih in kritičnih imisijskih vrednosti nevarnih snovi v tleh (Ur. L. RS 68/96), pojmuje da uporaba tal, ki vsebujejo:

- mejne imisijske vrednosti – učinki ali vplivi na zdravje človeka in okolje so še sprejemljivi;
- opozorilne imisijske – vrednosti je verjetnost škodljivih učinkov ali vplivov na zdravje človeka in okolje;
- kritične imisijske vrednosti – zaradi škodljivih učinkov ali vplivov na človeka in okolje onesnažena tla niso primerna za pridelavo rastlin, namenjenih prehrani ljudi ali živali.

Oljnice, ki jih pridelujemo na zemljiščih onesnaženih s težkimi kovinami je možno s pomočjo enostavnega postopka mehanske ekstrakcije predelati v energente ter gnojila in krmo (če niso presežene mejne vrednosti za težke kovine v gnojilih oziroma v hrani za živali).

Tehnologija za predelavo oljnic

Rastlinsko olje iz različnih oljnic se da proizvajati z mehansko ekstrakcijo ali pa s kemično ekstrakcijo s topili (heksan itn.). Proces proizvodnje olja z mehansko ekstrakcijo ne potrebuje zahtevnih postopkov in naprav v primerjavi s procesom proizvodnje olja s kemično ekstrakcijo s topili (ekološko sporno in nevarno za delo). Pomembna lastnost mehanskega procesa ekstrakcije je, da potrebuje nizke vložke energije in ne potrebuje uporabo vode in kemikalij. Stroji za mehansko ekstrakcijo olja so relativno enostavne konstrukcije, delujejo kontinuirano in ne potrebujejo nobene posebne skrbi pri delovanju. Zaradi možnosti proizvodnje olja s stiskanjem v okvirju majhnih proizvodnih enot se zadnje čase v svetu in v državah EU razširjajo decentralizirani proizvajalci rastlinskega olja za različne namene (predelajo od 0,01 do 5 t/dan). Mehansko iztiskanje semena se opravlja z mehanskimi kontinuiranimi stiskalnicami vijačnega tipa. Glede temperature vhodne surovine razlikujemo hladen ali topel postopek stiskanja. Pri hladnem postopku je temperatura vhodne surovine do maksimalno 25˚ C, temperatura olja na izhodu pri hladnem stiskanju pa mora biti pod 40˚ C. Stiskanje je lahko eno ali dvofazni proces. Pri dvofaznem iztiskanju lahko dosežemo, da iz semena oljne ogrščice iztisnemo tudi do 38 % olja.

Energetske prednosti rastlinskega olja

- alternativa za mineralno dizelsko gorivo
- tekoče gorivo visoke energetske vrednosti, ki ga lahko proizvaja kmetija z enostavnim postopkom mehanske ekstrakcije iz semena oljnic (stiskanje semena oljnic s stiskalnicami za oljnice)
- majhna poraba energije za proizvodnjo čistega rastlinskega olja iz semena oljnic (nižja poraba energije, kot pri proizvodnji npr. biodizla ali bioetanola)
- dostopno na kmetijah, ki pridelujejo oljno ogrščico ali druge oljnice in se ukvarjajo s postopkom hladnega ali toplega stiskanja olja
- tehnologija za proizvodnjo olja s postopkom mehanske ekstrakcije je cenovno dostopna širšemu krogu uporabnikov
- nižji transportni stroški goriva zaradi lokalne proizvodnje

Ekološke prednosti uporabe rastlinskega olja

- obnovljivi vir energije
- zaprti krog CO_2
    - biorazgradljivost (v treh tednih se razgradi 99 % v primeru razlitja po tleh)
    - netoksičnost (ni nevarnosti vdihovanja toksičnih ali karcinogenih plinov pri zgorevanju, ni nevarnosti v stiku s kožo itn.)
    - majhno onesnaževanje okolja v primeru razlitja pri transportu in manipulaciji (razred 0 glede onesnaževanja vode)
    - zmanjšanje emisij toplogrednih plinov CO_2, CO, PAH, ogljikovodikov itn. pri zgorevanju v dizelskih motorjih ni emisij žvepla
    - emisije trdnih delcev so zmanjšane za 50 – 70 % v primerjavi z mineralnim dizelskim gorivom
    - popolno zgorevanje zaradi večje vsebine O_2 v gorivu (ni črnega dima iz izpuha pri preobremenitvi motorja)
    - ne hlapi v zrak kot mineralna goriva

- enostavna proizvodnja
- težko vnetljivo (varno pri manipulaciji, transportu in skladiščenju zaradi visoke temperature vžiga)
- gorivo se transportira predvsem lokalno in ne iz oddaljenih delov sveta, posledično manjše onesnaževanje ozračja zaradi krajših transportnih poti goriva

Gospodarske prednosti proizvodnje rastlinskega olja

- vključevanje kmetijstva v verigo oskrbovalcev z energijo
- stranski produkt proizvodnje olja se uporablja za prehrano živali (manjša odvisnost od uvoza krmil iz tujine), večja ponudba krmil na domačem trgu pomeni tudi posledično nižje cene hrane
- odpiranje novih delovnih mest v kmetijstvu in predelovalni industriji
- nove rešitve na področju dizelskih motorjev ter njihove nove izvedbe za pogon na rastlinska olja predstavljajo možnost za odpiranje novih delovnih mest v industriji in storitveni dejavnosti

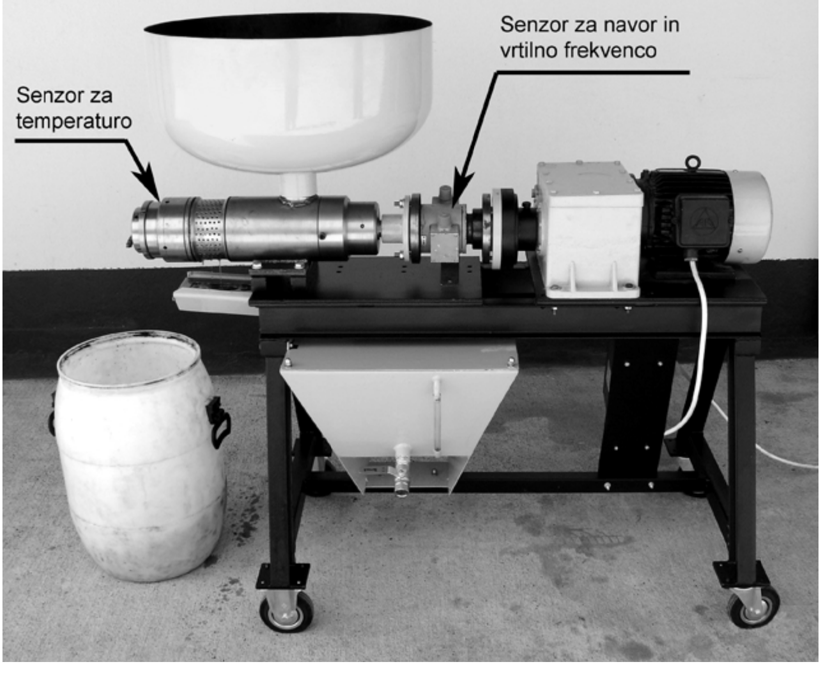
Kmetijske prednosti decentralizirane proizvodnje rastlinskega olja

- ob decentralizirani proizvodnji olja za energetske namene s postopkom hladnega ali toplega stiskanja olja nastaja, kot stranski produkt krma za prehrano živali (oljne pogače oziroma peleti)
- izkoriščanje zemljišč v zaraščanju za pridelavo npr. oljne ogrščice
- oljnice so pomembne za kolobar
- decentralizirana proizvodnja olja s stiskanjem oljne ogrščice ali drugih oljnic omogoča kmetom, da dosegajo višjo dodano vrednost na kmetiji
- visoka hranilna vrednost oljne pogače iz semena oljne ogrščice (10 – 17 % olja v oljni pogači)

MATERIAL IN METODE

Želeli smo ugotoviti ali se s tehnologijo mehanske ekstrakcije semena oljne ogrščice (mehansko stiskanje s stiskalnico kontinuiranega tipa po dvofaznem postopku) pridelane na zemljiščih onesnaženih s težkimi kovinami da proizvajati rastlinsko olje in oljno pogačo ustrezne kakovosti (glede pravilnika, kjer so določene mejne vrednosti težkih kovin v živalski in človeški hrani). S poskusom hladnega stiskanja semen različnih hibridov oljne ogrščice smo želeli ugotoviti tudi porabo energije za stiskanje semena ter distribucijo težkih kovin v olju in pogači iz različnih hibridov oljne ogrščice, ki je bila gojena na različnih lokacijah na zemljiščih kontaminiranih s težkimi kovinami.

Za raziskavo smo izbrali semena hibridov PR45 D01, PR46 W31 in PR45 D03 oljne ogrščice (*Brassica napus* L. var. *napus*), proizvajalca Pioneer d.d., ki se v Sloveniji najpogosteje uporabljajo za pridelavo olja. PR45 D01 je hibrid z vstavljenim genom pritlikavosti; pritlikava rast zmanjšuje nevarnost poškodb zaradi mraza. PR46 W31 je hibridno ozimna ogrščica, z visokim pridelkom zrnja in olja ter z nizko vsebnostjo glukozinolatov. Je srednje visoka in izjemno stabilna v različnih ekoloških pogojih. Vsebnost olja v semenih hibrida PR45 D01 je 42.7 %, medtem ko ga je v semenih hibrida PR46 W31 43,6 % . PR45 D03 je srednje zgodnji hibrid in ima za 1,5 % višjo vsebnost olja v primerjavi s hibridom PR45 D01. Odlikuje ga nizka rast jeseni, ne formira stebla in s tem omogoča odlično prezimitev. Odporen je na lomljenje in poleganje. Vzorčna mesta smo izbrali glede na rezultate predhodnih raziskav, ki so pokazale veliko obremenjenost tal ter vrtnin s težkimi kovinami na območju Celja, Mežice in Črne na Koroškem. Semena hibridov PR45 D01 in PR46 W31 oljne ogrščice smo posejali v Medlogu, Črni na Koroškem in v Mežici. V Šentjurju smo posejali hibrid PR45 D03. Za potrebe raziskave smo odvzeli naključne vzorce na različnih delih zasejanih površin.

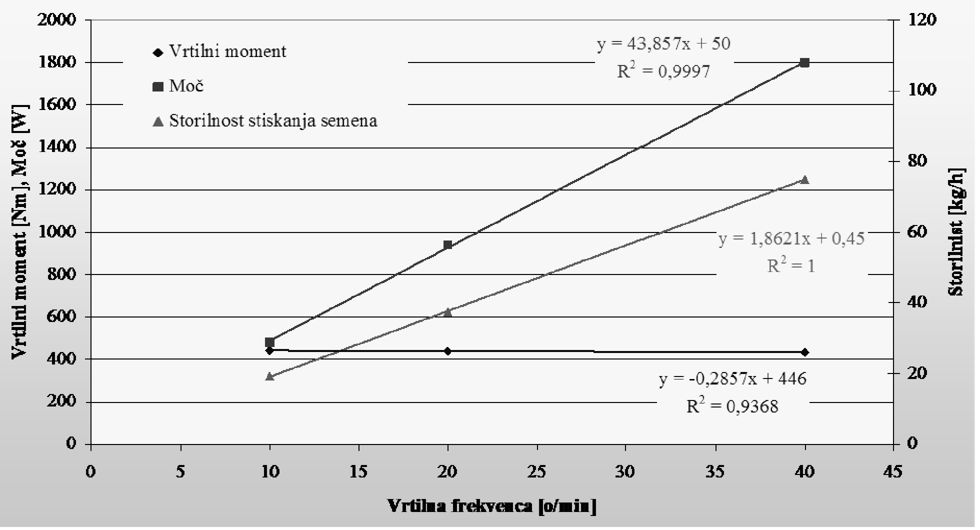


Slika 1 Eksperimentalna vijačna stiskalnica za kontinuirano stiskanja semena različnih oljnic (na stiskalnici smo opravili dvofazno stiskanje semena oljne ogrščice), omogoča variiranje vrtilne frekvence in navora ter geometrije stiskalnega dela, opremljena je s senzorji za spremljanje vrtilne frekvence, navora in temperature. Premer vijaka: 100 mm; premer izstopne šobe: 6 mm, 8 mm, 12 mm; vrtilna frekvenca vijaka: 5 – 50 vrt./min.; maksimalni učinek: 50 kg/h (vstopnega semena); priključna moč: 3 kW; Stiskalnica je razvita na Kmetijskem inštitutu Slovenije, Oddelku za kmetijsko tehniko

Stiskanje treh hibridov (PR45 D01, PR46 W31 in PR45 D03) je potekalo v dveh fazah. Na podlagi predhodnih raziskav, ki smo jih opravili na Kmetijskem inštitutu Slovenije smo se odločili za vrtilno frekvenco vijaka 20 obratov/min. za prvo fazo stiskanja in 10 obratov/min za drugo fazo stiskanja. Premer stiskalne šobe (skozi šobo prihajajo peleti premera 6 mm) je znašal 6 mm. Stiskalnica za potrebe raziskovanja procesa stiskanja se sestoji iz stiskalnega dela, ki ga predstavljajo: vijak za transport in stiskanje semena, cev z izvrtinami skozi katere prihaja olje in stiskalne glave s pušo skozi katero prihaja stisnjeno seme v obliki peleta. Med stiskalnim delom in pogonsko enoto (elektromotor s frekvenčnim regulatorjem) je nameščen dinamometer T30 FN Hottinger Baldwin za merjenje navora in senzor za določanje vrtilne frekvence. Elektromotor je bil povezan s frekvenčnim regulatorjem tako da se za potrebe raziskav izbere ustrezna vrtilna frekvenca vijaka za transport in stiskanje semena. Na zgornjem delu stiskalne cevi je pritrjeno nasipno ustje za seme oljaric. Seme, ki gravitacijsko prihaja iz nasipnega ustja prihaja do horizontalno vležajenega vijaka, ki ga z vrtenjem transportira do stiskalnega dela – stiskalne glave, kjer se seme stisne. Na stiskalni glavi je bil nameščen senzor za ugotavljanje temperature olja. Olje, ki prihaja iz semena se vrača v nasprotni smeri od smeri vrtenja vijaka in teče na izvrtine na cevi. Stisnjeno seme pa vijak izriva iz stiskalne glave skozi pušo, kjer se formira v izstopni šobi v pelete. Celotni stiskalni in pogonski del je pritrjen na nosilno ogrodje.

REZULTATI IN DISKUSIJA

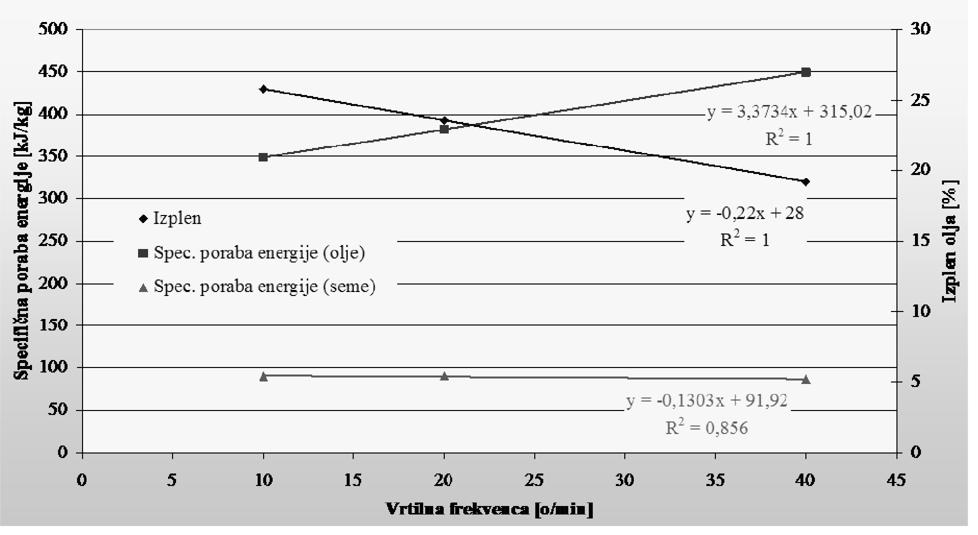
Zaradi ekonomičnosti stiskanja je potrebno iztisniti čim večjo količino olja iz semena. To dosegamo z dvofaznim načinom stiskanja, kjer enkrat stisnjeno seme oziroma produkt stiskanja še enkrat spustimo skozi stiskalnico. Največja količina olja je v raziskavah stiskanja dobljena z dvofaznim načinom stiskanja semena oljne ogrščice. Preizkusili smo tudi trifazno stiskanje vendar so dobljene količine olja zanemarljive, da bi bilo ekonomično opravljati trifazno stiskanje semena oljne ogrščice.



Slika 2 Vrtilni moment *M* (Nm), moč *P* (W) in storilnost pri mehanski ekstrakciji olja (enofazno stiskanje, šoba za iztiskanje semena na stiskalni glavi ima premer 6 mm ter formira pelet iz semena iz katerega je iztisnjeno olje)

Ugotovili smo, da z naraščanjem vrtilne frekvence stiskalnega polža narašča moč *P* (računsko določena iz produkta vrtilnega momenta *M* in kotne hitrosti ω stiskalnega polža) in storilnost stiskanja. Vrtilni moment je skoraj konstanten na celotnem območju vrtilnih frekvenc (za ugotavljanje porabe energije smo uporabili vrtilno frekvenco 10, 20 in 40 obrat./min.).

Z naraščanjem vrtilne frekvence stiskalnega polža se specifična poraba energije E_{sp} povečuje, izplen olja pa zmanjšuje. S stališča energetske porabe in izplena olja je najbolje uporabljati čim nižje vrtilne frekvence (za ugotavljanje porabe moči smo uporabili vrtilno frekvenco 10, 20 in 40 obrat./min.).



Slika 3 Specifična poraba energije E_{sp} (kJ/kg iztisnjenega olja) in izplen olja (%), enofazno stiskanje (šoba za iztiskanje na stiskalni glavi premera 6 mm)

Po prvem in drugem stiskanju hibridov oljne ogrščice smo opravili tehtanje olja in oljne pogače. V drugem stiskanju vstopne mase oljne pogače ter olja in olje pogače na izstopu.

Naši rezultati kažejo, da je masa olja največja pri hibridu PR45 D01 (39,8 %), sledi mu hibrid PR46 W31 (36,6 %) in hibrid PR45 D03 (34,5 %). Po vsakem stiskanju se poveča celokupna masa olja. Najnižja masa olja je bila izmerjena pri hibridu, ki je rasel na tleh brez preseženih imisijskih vsebnosti težkih kovin. Največje vsebnosti so bile izmerjene pri hibridoma PR45 D01 in PR46 W31, ki sta rasla na tleh, kjer so bile presežene opozorilne imisijske vrednosti Cd in Pb ter mejne imisijske vrednosti Ni in Co.

Merjene so bile težke kovine v olju po prvem in drugem stiskanju hibridov PR45 D03, PR45 D01 in PR46 W31. Ugotovljeno je, da so vrednosti težkih kovin pod mejo detekcije za Mo, Ni, Co, Ba, Zn, Cu, As ter Pb in Cd za hibrid PR45 D03, ki je rasel na neonesnaženih tleh. Nad mejo detekcije pa so bile izmerjene vrednosti pri hibridih PR45 D01 in PR46 W31, ki sta rasla na srednje onesnaženih tleh in sicer za Pb po prvem in drugem stiskanju obeh hibridov ter za Cd po prvem stiskanju pri hibridu PR45 D01. V preglednici opazimo, da so nekoliko večje vrednosti Pb izmerjene po prvem stiskanju hibridov PR45 D01 in PR46 W31. Enaka opazka velja za Cd pri hibridu PR45 D01.

Preglednica 1 Vsebnost olja in pogače po 1. in 2. stiskanju hibridov PR45 D03, PR45 D01 in PR46 W31

	PR45 D03		PR45 D01		PR46 W31	
1. stiskanje	kg	%	kg	%	kg	%
Masa semen	26,88		9,86		19,28	
Masa olja	6,34	23,59	2,94	29,82	4,38	22,72
Masa pogače	20,54	76,41	6,92	70,18	14,9	77,28
2. stiskanje						
Masa olja	2,93	14,29	0,98	14,21	2,67	17,93
Masa pogače	17,61	85,71	5,94	85,79	12,23	82,07
Skupaj						
Masa olja	9,27	34,50	3,92	39,79	7,05	36,58
Masa pogače	17,61	65,50	5,94	60,21	12,23	63,42

Preglednica 2 kaže, da večje kot so vsebnosti Pb in Cd v tleh, večje so vsebnosti Pb in Cd v rastlinskih delih (korenine, stebla in semena) in posledično tudi v pogači in v olju hladno iztisnjenih semen.

Preglednica 2 Vsebnosti težkih kovin v olju po prvem in drugem stiskanju semen hibridov PR45 D03, PR45 D01 in PR46 W31.

	mg/kg	**Mo**	**Ni**	**Co**	**Pb**	**Cd**	**Ba**	**Zn**	**Cu**	**As**
Šentjur **PR45 D03**	I. stiskanje	<0.1	<1	<0.1	<0.1	<0.01	<1	<10	<1	<0.1
	II. stiskanje	<0.1	<1	<0.1	<0.1	<0.01	<1	<10	<1	<0.1
Črna na Koroškem **PR45 D01**	I. stiskanje	<0.1	<1	<0.1	**0,4**	**0,01**	<1	<10	<1	<0.1
	II. stiskanje	<0.1	<1	<0.1	**0,3**	<0.01	<1	<10	<1	<0.1
Črna na Koroškem **PR46 W31**	I. stiskanje	<0.1	<1	<0.1	**0,5**	<0.01	<1	<10	<1	<0.1
	II. stiskanje	<0.1	<1	<0.1	**0,2**	<0.01	<1	<10	<1	<0.1

ZAKLJUČEK

V naši raziskavi smo ugotavljali distribucijo težkih kovin v oljni ogrščici, ki je rasla na neonesnaženih tleh in na srednje onesnaženih tleh, kjer so bile prekoračene mejne vrednosti Ni in Co ter opozorilne vrednosti Cd in Pb, glede na slovensko zakonodajo (Ur. L. RS 68/96).

Največja masa olja je bila izmerjena pri hibridih oljne ogrščice PR45 D01 in PR46 W31. Večje kot so vsebnosti Pb in Cd v tleh, večje so vsebnosti Pb in Cd v rastlinskih delih (korenine, stebla in semena) in posledično tudi v pogači in v olju hladno iztisnjenih semen.

Glede na slovensko zakonodajo (Ur. L. RS 69/03) dobljena olja iz hibridov oljne ogrščice PR45 D01 in PR46 W31 po I. in II. hladnem stiskanju semen prekoračujejo vsebnosti Pb v olju, kot živilu in bi ga bilo potrebno očistiti. Zato je alternativa uporaba omenjenega olja za energetske namene (za direktno uporabo, kot gorivo ali predelavo v biodizel). Pogača, dobljena pri stiskanju, je glede na Slovensko zakonodajo (Ur. L. RS št. 101/2006) primerna v proizvodih za prehrano živali.

Z naraščanjem vrtilne frekvence stiskalnega polža mehanske stiskalnice se specifična poraba energije E_{sp} povečuje, izplen olja pa zmanjšuje. S stališča energetske porabe in izplena olja je najbolje uporabljati čim nižje vrtilne frekvence stiskalnega polža.

Z uporabo enega od ukrepov remediacije, pozelenitvijo, ne samo, da je dosežena ekonomsko najbolj donosna sanacija ampak se tudi polepša krajina in s tem izboljša kvaliteta življenja ljudi, ki so izpostavljeni vplivom onesnaženih področij s težkimi kovinami. Na ta način bi lahko na malo do srednje onesnaženih tleh ponovno v prihodnosti vzpostavili pogoje za gojenje kmetijskih rastlin za prehrano živali oziroma za uporabo za energetske namene. Gojenje oljne ogrščice, kot energetske rastline je najbolj primerno na malo do srednje onesnaženih tleh, kjer rast in razvoj rastlin zaradi težkih kovin ni oslabljena. Ugotovili smo, da je oljno ogrščico potencialno možno gojiti povsod v Sloveniji, razen na območjih močne kontaminacije tal. Obnovitev in oživitev malo, srednje in močno kontaminiranih področij mora biti tako interes lokalnih skupnosti kakor tudi nacionalni in evropski interes.

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POSIBILITIES OF OSR ENERGY PRODUCTION GROWN AT HEAVY METALS CONTAMINATED AREAS

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SUMMARY

*In this paper we study the possibility of remediation of contaminated soil with heavy metal in the production of rapeseed for energy use and other purposes. We have done the mechanical extraction of rapeseed (*Brassica napus *L. var. napus) with a mechanical cold pressing of seeds with screw press of continuous type in a two stage process. We determined the energy consumption for pressing seeds and distribution of heavy metals in the oil and cake. We chose to investigate the hybrid seeds D01 PR45, PR46 and PR45 W31 D03 rape (*Brassica napus *L.* var. Napus*), which in Slovenia is the most widely used for oil production. We found that with increasing pressing screw speed the specific energy consumption increases and the yield of oil is falling. In terms of energy consumption and yield of oil it is better to use lower speeds of pressing screw. If the levels of Pb and Cd in soil are higher also content of Pb and Cd is higher in plant parts (roots, stems and seeds) and therefore also in the cake and cold-pressed seed oils. According to Slovenian legislation, oil obtained from hybrids PR45 and PR46 W31 D01 after the first and second cold pressing exceed the Pb content in oil, as food, so the oil is only suitable for energy purposes.*

Key words*: soil contamination, heavy metals, soil remediation, rape seed, mechanical extraction of vegetable oil*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

UDK 631. 147:631.6.02
Pregledni rad
Review paper

MODELI RASTLINSKE PRIDELAVE NA OBMOČJIH DEGRADIRANEGA OKOLJA

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POVZETEK

Po povrsini kmetijske zemlje v uporabi na prebivalca z 880 m^2 Slovenija zaostaja za EU in za splosno ugotovljenimi priporocili za samooskrbo (2000 m^2/prebivalca). Manjsanje razpolozljivih povrsin, primernih za pridelavo hrane, nas sili v iskanje novih resitev, kot je uporaba degradiranih obmocij. Potrebno je preuciti uporabo dodatnih kmetijskih zemljisc, ki bo omogocala pridelavo rastlin, primernih za clovesko ali zivalsko prehrano, za industrijske surovine (vlaknine za tekstil, izolacijske materiale, gradbene materiale itn.) in uporabo v energetske namene.

V članku je opisana metodologija priprave modelov za ohranitev in nadaljnji razvoj rastlinske proizvodnje na obmocjih degradiranega okolja. Priprava posameznega modela obsega analizo stanja okolja, ki ji sledi oblikovanje kriterijev in kategorizacija območij glede na vrsto in stopnjo degradacije (fizicna, kemijska, bioloska, ...) nato se definira nadaljnja uporaba biomase z degradiranih površin in pripravi scenarije mozne pretvorbe v kmetijsko rabo z razlicnimi ukrepi (od tehnicnih do kmetijsko tehnoloskih) za razlicen namen.

Ključne besede: *Degradirana obmocja, onesnazenost tal, pridelava hrane in krme, biomasa iz kmetijstva*

UVOD

Po površini kmetijske zemlje v uporabi na prebivalca z 880 m^2 Slovenija zaostaja za EU in za splošno ugotovljenimi priporočili za samooskrbo (2000 m^2/prebivalca). Zagotavljanje primernih količin hrane ob vedno bolj pogostih negativnih naravnih pojavih (potresi in popotresni valovi, vulkanski izbruhi,požari, toča, suša, ...) še dodatno otežujemo z antropogeno degradacijo okolja, kot sta pospešeno zmanjševanje kmetijskih površin zaradi ekonomskega razvoja (zazidava, ceste) in onesnaževanje tal zaradi posledic pretekle in sedanje industrijske in kmetijske aktivnosti. Onesnaženost tal običajno ni vidna, hkrati pa veliko onesnažil ostane v tleh tudi po prenehanju onesnaževanja in predstavljajo vir potencialno toksičnih snovi za človeka. Glavne poti vnosa v človeka so preko hrane, pridelane na onesnaženem območju. Zato je pri načrtovanju sanacijskih in remediacijskih ukrepov, s katerimi bi zmanjšali možne vplive onesnaženih tal na zdravje ljudi poleg zakonodaje potrebno upoštevati tudi rabo tal. Količino razpoložljivih površin za pridelavo hrane še dodatno zmanjšuje uporaba kmetijskih zemljišč za pridelavo energetskih rastlin. Manjšanje razpoložljivih površin, primernih za pridelavo hrane, nas sili v iskanje novih rešitev, kot je uporaba degradiranih območij.

METODE

Človeška aktivnost je, posebej v zadnjih 200 letih (industrijska doba), z onesnaževanjem dramatično spremenila sestavo in zgradbo tal. Poleg vidne fizične degradacije okolja poznamo tudi manj opazno biološko in kemijsko degradacijo tal in okolja. Rezultat vnašanja onesnažil v tla iz zraka, z odlaganjem odpadkov, uporabo fitofarmacevtskih sredstev in mineralnih gnojil in z izpusti in izlivi kemikalij (Leštan in sod., 1997) je povečana vsebnost mnogih toksičnih snovi. Skupna koncentracija elementov je v naravnih tleh različna, kar je pri vrednotenju stopnje onesnaženosti zelo pomembno. Naravno ozadje na primer za za kadmij v tleh je povprečno 0,35 mg/kg (0,01 – 2 mg/kg), za cink pa 90 mg/kg (10 - 300 mg/kg) tal (Adriano, 2006). Kadmij je živim organizmom neesencialen element, nasprotno je cink nujno potreben mikroelement, kjer se pri vsebnosti pod 50 mg/kg tal že lahko pojavijo znaki pomanjkanja pri rastlinah (Bergmann, 1992). Različne rastline se na iste koncentracije kovin različno odzivajo, ločimo akumulatorske, indikatorske in tolerantne rastline (Unterbrunner in sod., 2007). Učinkovitost sprejema kovin iz tal ali hranilne raztopine v rastlino podajamo z bioakumulacijskim faktorjem oziroma transportnimi količniki (Zupan in sod., 1995; Chojnacka in sod., 2005; Na Zheng in sod., 2007), na podlagi katerih lahko rastline razvrstimo v skupine glede na sprejem težkih kovin (Kloke in sod., 1984). Iz vidika vnosa kovin v prehranjevalno verigo je pomembna predvsem akumulacija v užitni del rastline pri čemer nam je v pomoč splošno pravilo, da največ kovin pride v rastlino preko korenin in se tam tudi zadrži; le del se transportira v nadzemne dele, kjer poteka akumulacija v vakuolah listnih celic, najmanj akumulacije poteka v tkiva semen oziroma plodov (Bergmann, 1992; Zupan in sod., 1995; You-Jing in sod., 2004; Na Zheng in sod., 2007). Rastline lahko preprečujejo prehajanje kovin v rastlino ali pa jih akumulirajo v tkivih in z uporabo notranjih mehanizmov zmanjšajo škodljive vplive (Baker, 1981). Akumulatorske rastline so odporne na kovine in imajo razvejan koreninski sistem (Brooks, 1998). Fitoremediacija je atraktiven, estetski, ekološki, ekonomski in javnosti sprejemljiv pristop čiščenja kovin iz tal (Entry et al. 1997).

Rastline, primerne za fitoremediacijo oziroma fitoekstrakcijo, naj bi bile tolerantne na visoke vsebnosti kovin v tleh (Baker in Walker, 1990; Brooks, 1998), akumulirale naj bi velike količine kovin v nadzemnih rastlinskih delih, hitro rastle, tvorile veliko nadzemne rastlinske mase in imele globok koreninski sistem (Garbisu in Alkorta, 2001). Uporaba rastlin za čiščenje onesnaženih tal je znana približno 300 let (Lasat M. M., 2000). Z odstranjevanjem onesnažene biomase na kmetijskih površinah lahko čistimo onesnažena tla na sonaraven in trajnostni način (Ribarič in sod., 2007).

Omejitev fitoekstrakcije je sicer njena majhna učinkovitost, saj je potrebnih več desetletij, pri nekaterih kovinah in večji stopnji onesnaženosti tal celo stoletij, da zmanjšamo vsebnost kovin do take mere, kot jih predpisuje zakonodaja. Kljub temu je fitoekstrakcija primeren način remediacije tal za površine z nizko do srednjo stopnjo onesnaženosti na pri-urbanih kmetijskih površinah. Na takih površinah bi prenehanje obdelave tal oziroma negovanja kmetijskih površin pomenila novo grožnjo tlom – t.j. pozidavo oziroma drugo nepovratno degradacijo. Zato je smiselno gojenje rastlin s fitoekstrakcijskim potencialom in veliko biomaso, ki imajo hkrati tudi energetsko vrednost oziroma je dele rastlin možno predelati v gorivo ali industrijske surovine. Na ta način ohranimo zaposlitev kmečkega prebivalstva, tla ostanejo v primarni funkciji proizvodnje biomase, hkrati pa se status vsebnosti anorganskih nevarnih snovi dolgoročno zmanjšuje. Tak način rabe tal potrebuje kontrolo vpliva onesnaženih tal na sosednje ekosisteme in preprečevanje erozijskih procesov.

Za kakovostno direktno setev v strnišča na kontaminiranih zemljiščih je potrebno uporabiti adekvatno tehnologijo. Z uporabo klasične izvedbe krožnih bran, ki so namenjene za drobljenje rastlinskih ostankov z večjimi delovnimi hitrostmi in njihovo delno inkorporacijo v tla, ni mogoče kakovostno opraviti razreza rastlinske mase – žetvenih ostankov. Slaba lastnost je, da puščajo na površini veliko količino rastlinske mase, ki ni prerezana, kar pomeni veliko oviro za direktno setev (s tem je povezana kakovost odlaganja semena in setve). V Nemčiji so delali poskuse (Köller in Wiesehoff 2005) z različnimi elementi za setev v strnišče (elementi za razrez in za odstranjevanje rastlinskih ostankov). Elementi, ki odstranjujejo rastlinske ostanke, so bili v delovanju primerjani z elementi, ki razrezujejo rastlinske ostanke. Elementi, ki razrezujejo rastlinske ostanke, so se pokazali kot boljši v primerjavi s prej omenjenimi elementi, ki odstranjujejo rastlinske ostanke.

Riva in Sissot (1999) navajata, da je med rastlinami več kot 4000 takšnih, iz katerih se da ekstrahirati olje (primarno iz semena). V industrializiranih državah se za proizvodnjo olja največ uporabljata oljna ogrščica in sončnica. Za proizvodnjo energije lahko uporabljamo nerafinirana kakor tudi rafinirana rastlinska olja do različnih stopenj (enostavno filtriranje, ekstrakcija voskov in gumijastih delov, esterifikacija itd.). Tack (2004) navaja, da decentralizirane proizvodne enote za mehansko ekstrakcijo olja lahko ekonomsko in okolju prijazno obratujejo, če je njihova tehnična oprema in delovni proces čim bolj enostaven ter povezan z nizko porabo energije. Profitabilnost decentralizirane proizvodnje olja je odvisna od: višine investicije, trajanja delovne sezone, stroškov za seme, prodajne cene oljnih pogač in vloženega človeškega dela.

V preteklosti so za čiščenje onesnaženih tal zagovarjali procese saniranja z odkopavanjem kontaminiranih plasti tal in razvažanjem omenjenih tal na druge lokacije. Omenjena metoda je energetsko, časovno in okoljsko sporna. Za odkopavanje je potrebno angažirati posebne stroje za izkop (gradbene, rudniške itn.) in urediti odvoz materiala. Za pogon omenjenih strojev se uporablja energija fosilnih goriv, ki prispeva k ustvarjanju emisij CO_2 in drugih toplogrednih plinov. Metoda zahteva ogromno časa, pri izkopu pa nastaja tudi prah, ki ga lahko veter prenaša na velike razdalje. Poleg tega se problem onesnaženosti samo prenese z enega na drugo območje.

Analiza stanja in kategorizacija degradiranega okolja v Sloveniji

Za analiza stanja smo vključili kritično presojo rezultatov preiskav degradiranih območij v Sloveniji in opravili pregled domače ter tuje literature s poudarkom na uspešnih tujih praksah revitalizacije degradiranih tal. Pregledali smo obstoječe evidence in jih dopolnili oz. uredili v sistemu stopenjske kategorizacije pri čemer prvo stopnjo predstavlja osnovna razvrstitev degradiranega okolja:

1. Fizično degradirano okolje (gramoznice, kamnolomi, glinokopi...);
2. Kemijsko onesnažena zemljišča (toksične kovine, PAH, PCB, dioksini...);
3. Biološko »mrtva« tla, mineralna zemljina (horizont) brez humusa;
4. Drugo.

Prvi fazi sledita po potrebi še druga in tretja faza in nadaljnje stopnje kategorizacije degradiranih tal, ki predstavlja osnovo za pripravo kriterijev in možnih modelov rabe. V nadaljevanju je potrebno opraviti še pregled stanja obstoječih tehnologij obdelave tal primernih za degradirana območja in definirati tehnologije za racionalno obdelavo tal, ki so primerne za degradirana območja.

Zakonodaja in kriteriji za vrednotenje degradiranih območij

Eden od osnovnih kriterijev za vrednotenje degradiranega okolja je zakonodaja, kjer je potrebno proučiti 'pristojnosti' posameznih zakonov in uredb, ki je lahko na degradiranem okolju problematična (na primer navožen oporečen material na kmetijskem zemljišču, ki ga lahko obravnavamo iz vidika zakonodaje o odpadkih ali kako drugače). V sistem kriterijev je potrebno vgraditi tudi nabor parametrov, ki so potrebni za izgradnjo modelov rabe tal:

- osnovne karakteristike tal (tekstura, globina tal, vsebnost in dostopnost hranil, voden karakteristike tal, skeletnost, ...) na lokaciji;
- druge prostorske informacije: podzemne in nadzemne vode, vodovarstvena območja, Natura 2000, EPO, druga varovana območja, ki s svojimi omejitvami lahko predstavljajo nujne in/ali robne pogoje za rabo degradiranih območij.

Definiranje nadaljnje uporabe biomase z degradiranih površin

V tej fazi je potrebno:

- definirati način nadaljnje uporabe ostankov energetskih rastlin nastalih v proizvodnji obnovljive energije, glede ostankov škodljivih snovi (pepel, digestat iz bio plinskih naprav, oljna pogača iz stiskanja oljnic itn.);
- povezovati obstoječe in sodobne tehnologije za obdelavo tal ob upoštevanju porabe energije pri različnih sistemih obdelave tal (konvencionalna, konzervacijska in »no

till«) in preučiti možnosti zmanjševanja porabe energije v obdelavi tal (zmanjševanje emisij CO_2);

- Definirati tehnologije za obdelavo tal glede izboljšave pedoloških in hidroloških lastnosti tal (mehanski ukrepi) ob upoštevanju rezultatov ekonomske analize različnih sistemov obdelave tal (konvencionalna, konzervacijska in »no till«).

Pri reševanju naštete problematike pa ne smemo pozabiti na izkoriščanje potenciala tal v obliki ponora CO_2 in imeti pregled nad stanjem na področju sistemov za izkoriščanje obnovljivih virov energije ter ustreznimi tehnologijami za predelavo energetskih rastlin v energente (trdne, tekoče in plinaste).

Izdelava modelov za degradirana območja

Za vsako od navedenih degradacij (glede na kategorije in podkategorije) je potrebno pripravili modele različnih načinov sanacije oziroma rabe s ciljem vzpostaviti pogoje za pridelavo/proizvodnjo hrane in/ali krme in/ali vlaknin in/ali energije. V modelih morajo biti vključene različne opcije koriščenja tal glede na obstoječe ali možno potencialno rabo tal:

- Njive: ustrezna izbira kolobarjev (poljedeljski, zelenjadarski, kombinirani,...; specifična raba tudi glede na lastnosti privzema nevarnih snovi npr. kovin v rastline);
- Trajno travinje: pašniki in travniki (pretežno krma, alternativna energija, ...)
- Trajni nasadi: zelnate trajnice, grmi, drevesa,... (pretežno energija, lahko tudi surovine)

V modele morajo biti vključeni tudi potencialni materiali za rekultivacijo glede na vrsto in stopnjo degradacije: komposti, gnojevke (tudi bioplinske), mulji, mineralni izboljševalci tal in drugo (kdaj lahko kaj uporabimo). Uporaba biomase mora biti zajeta v smislu predelave in uporabe biomase za energetske namene.

Testiranje modelov

Za izbrana območja z različno kategorijo in stopnjo degradacije je možno pripraviti scenarije revitalizacije oziroma bodoče rabe tal s ciljem ohranitve rastlinske pridelave za hrano, krmo in/ali energijo oziroma druge surovine. Scenariji morajo biti narejeni na osnovi konkretnih obstoječih podatkih trenutne rabe ter stanja degradacije in morajo, zaradi boljše in lažje obveščenosti širše javnosti, vključevati tudi nazorne grafične predloge.

REZULTATI Z RAZPRAVO

Medresorska delovna skupina državnih sekretarjev za izvajanje zavez Parmske deklaracije (ustanovljena v letu 2010) je evidentirala območja v Sloveniji, za katera se ocenjuje, da so prekomerno onesnažena z različnimi onesnažili in zato predstavljajo dodaten dejavnik tveganja za zdravje.

Onesnaženost okolja lahko razdelimo glede na vir onesnaženja in glede na onesnažilo, ki je v določenem okolju problem.

Industrijsko onesnaženje

- azbest (Anhovo; urbane in kmetijske površine v okolici);
- onesnaženost s kovinami in metaloidi (As, Cd, Hg, Pb, Zn) zaradi rudniške in topilniške dejavnosti (Zgornja Mežiška dolina, Idrijsko, Spodnja Soška dolina in Tržaški zaliv, Zasavje, Celjska kotlina, okolica Maribora, Jesenice, Okolica rudnika Sitarjevec (občini Litija in Šmartno));
- VOC (hlapne organske spojine), ftalati in AFK (Velenje, Šoštanj in Koper);
- hrup (Zreče);
- PCB (Semič);
- prah, PM10 (Zasavje, Laško, Zidani most);
- radioaktivna jalovina (Žirovski vrh, okolica Kočevskega rudnika).

Kmetijstvo

- fitofarmacevtska sredstva in nitrati (točkovno na intenzivnih kmetijskih območjih v RS (polja na aluvijalnih ravninah - Sorško polje, Kranjsko polje, Krško polje, Ljubljana z okolico, Savinjska kotlina, Dravsko in Ptujsko polje, Mursko polje; plantažni nasadi in vinogradi).

Promet

- ozon in tributilkositrove spojine (Primorska);
- prašni delci, ozon, Nox, CO_2, PAH, VOC, SO_2, hrup (velika mesta).

Drugo

- cvetni prah pelinolistne ambrozije (Vzhodna Slovenija);
- emisije plinov (metan, CO_2), izcedne vode (registrirana odlagališča odpadkov);
- fekalno onesnaženi viri pitne vode (kraški viri pitne vode);
- hrup (gradbišča, prireditveni prostori, kjer se uporabljajo zvočne naprave, ladijski promet-specifika v Kopru; pristanišče, potniški terminal);
- mikrobiološko in kemično onesnaženje (neurejen kanalizacijski sistem v Primorski in Pomurski regiji);
- herbicidi (železniške proge);
- PM10 (individualna kurišča, predvsem v predmestjih in na podeželju);
- strupene kovine, organske spojine, (POP´s) (ilegalna odlagališča odpadkov);
- fluoridi (občasne prekoračitve v okolici Kidričevega);
- visoke vsebnosti Cu v starejših vinogradih (potencialna nevarnost ob spremebi rabe tal);
- geogeni izvor Cr in Ni na krasu in flišu v JZ Sloveniji.

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MODELS OF PLANT PRODUCTIONS ON DEGRADED AREAS

SUMMARY

MIRAN LAKOTA, HELENA GRČMAN, MARKO ZUPAN, VIKTOR JEJČIČ, BOŠTJAN GRABNER, NADJA ROMIH, CVETKA RIBARIČ LASNIK

By area of agricultural land in use per capita of 880 m^2 Slovenia lags behind the EU and the general recommendations found in subsistence (2000 m^2/resident). Reduction of the available land suitable for food production forces us to seek new solutions, such as the use of degraded areas. It is necessary to consider the use of additional agricultural land, which will enable the production of plants suitable human or animal consumption, raw materials for industrial purposes (fibre for textiles, insulation materials, building materials, etc.) and for energy purposes.

The paper deals with the modelling methodology for the preservation and further development of vegetable production in the less degraded environment. For each model the first step present the analysis of the environment state, followed by building degrees of degradation and categorisation of environmental degradation (physical, chemical, biological, ...). The final step is definition of further use of biomass in degraded areas and preparation of possible conversion to agricultural use through various measures (from technical to agricultural technology) for a different purpose.

Key words: *degraded areas, soil pollution, food production and feed, biomass from agriculture*

40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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APPLICATION OF LIFE CYCLE COST METHOD FOR WILLOW PRODUCTION MACHINERY

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SUMMARY

The paper proposes a method based on Life Cycle Cost (LCC), for decision making process in agricultural engineering, especially in equipment acquisition. The purpose of this paper is to provide one application which uses life cycle cost for a system of interest (including individual agricultural systems, system of agricultural associations, and production and business in agriculture equipment), from an early conceptual stage in the product life cycle through to disposal. Also, it provides illustrations on the types of life cycle cost studies that can be conducted and examples to demonstrate the benefits of conducting life cycle cost to inform the decision making process. Life cycle cost analysis was considered not as a one-off task and has been used for analysis of a project concerning energetic willow cultivation in Banat Region. Three scenarios were estimated in different surfaces of the growing area

***Key words**: Life Cycle Cost, willow, machinery*

INTRODUCTION

General strategies establish the target of 20% share of renewable energy by 2020, together with energy savings and increasing of energy efficiency, as important parts of the complex package of measures needed to reduce GHG emissions (Directive, 2009/28/EC).

On the other hand, energy demand is complex and supposes a lot of conditions, risks, costs, disparities, constraints etc., in conditions of energy demand that increases and imposes special solutions to avoid environmental influences and insures low general costs (economic, social etc.), (Tucu D., Hollerbach W., 2011).

One solution, integrated in such strategies is the use of short rotation crops (SRC) as a potential source of biomass for energy generation and bioproducts.

Perenial energy crops like short rotation woody crops (SRWC) and herbaceous crops (SRHC) could be an essential component of the supply of biomass feedstock around the world in the coming years (Buchholz T. et al., 2010; Hoogwijk M. et al., 2005).

Willow for energy (Energetic Willow or Salix Viminalis), is one SRWC that has been identified as having good potential for large scale deployment in Romania, and many favorable characteristics (Hollerbach W., et al. 2009):

- can be used as biomass (hash), briquettes or pellets; - creation of new jobs for unskilled people and for unused machines, because harvesting is done in the months from November to March, a period when agricultural machinery is not used for anything else;
- willow can grow (recommended) on permanent or periodical wetlands, evapo-transpiration has a capacity of 15-20 l water/day; this advantage gives an undisputed place as the plant used to make thousands of hectares of land;
- transportation costs and emissions are lower for strategically situated willow crops compared to forest harvesting or annual agricultural crops as yields are greater or comparable, but inputs reduced and only a portion of the planted area is harvested annually (Turnbull HJ, 1994);
- the overall net energy balance of chipped willow biomass up to and including harvest is between 1:55 and 1:80, depending on whether commercial fertilizer or organic amendments are used (Heller M.C. et al., 2003);
- perennial nature and extensive fine-root system reduces soil erosion, promote stable nutrient cycling and enhance soil carbon storage in roots and soil; willow crop uses the marginal agricultural land and offer good space for bird species than richness, nesting density and reproductive success in willow crops comparable to natural shrublands (Dhondt A. et al. 2007);
- willow Salix Viminalis Energo - is highly resistant to different weather conditions.

Therefore, large amounts of biomass can be grown on relatively small areas.

Till now, the economic analysis of willow coppice culture for different European countries had different objectives:

- financial comparison with other agricultural products from other regions, like Rosenquist and Dawson for Ireland (Rosenqvist H. et al., 2005), Poland (Ericsson K. et al. 2006) etc.;
- the Energy Crop Calculator developed by several UK agencies ;
- financial viability of using shrub willow as an wastewater treatment system in Ireland (Rosenqvist H. et al., 2005).

Nevertheless, a possibility for comprehensive economic analysis of the basic production schemes for willow crops under Romanian (also central Europe) conditions is still lacking (Andea P., et all. 2010).

Present paper proposes a new method for examine the economic performance of willow culture in different conditions: economical, energetic, managerial, social and environmental, by using Life Cycle Cost method. The results will be used for decision regarding equipment acquisition.

MATERIALS AND METHODS

Material

Selecting the area, energetic plant, technologies and equipment based on a life cycle cost analysis from more alternative (scenarios), can significantly decrease the lifetime cost of the project in all stages: concept and design, implementation, maintenance, repair and recycling (land recuperation) and for entire project.

The most important cost in willow cultivation is that for planting machine and harvesting equipment. As material were considered in this paper decision for acquisition of planting and harvesting equipment in different alternatives, corresponding to values from 10000 EUR to 500000 EUR.

Method developing

The first component in a LCC equation is the costs. There are two major cost categories by which projects are to be evaluated in a LCC analyses or introduce life cycle cost analyses (LCCA). They are Initial Expenses and Future Expenses. Initial Expenses are all costs incurred prior to developing the project (documentation, decision, analyze, land procurement, realizing of the culture in first year). Future Expenses are all costs incurred after the realizing of the project (starting from second year of the culture, including expenses for removal). The individual costs will be evaluated within the two major cost categories, defining the exact costs of each expense category that can be somewhat difficult since, at the time of the LCC study, nearly all costs are unknown. However, through the use of reasonable, consistent, and well-documented assumptions, a credible LCCA can be prepared.

One should also note that not all of the cost categories are relevant to all projects. The preparer is responsible for the inclusion of the pertinent cost categories that will produce a realistic LCC comparison of project alternatives. If costs in a particular cost category are equal in all project alternatives, they can be documented as such and removed from consideration in the LCC comparison.

One future expense that warrants further explanation is that of residual value, the net worth of a project at the end of the LCCA study period. Unlike other future expenses, an alternative’s residual value can be positive or negative, a cost or a value.

The second component of the LCC equation is time, study period, as period of time over which ownership and operations expenses are to be evaluated, which can range from twenty five to thirteen years, depending on owner’s preferences, the stability of the user’s program, and the intended overall life of the facility.

As mentioned, the study period is split into two phases: the planning/construction period (culture start-up), and the service period (culture maintenance and exploitation and culture removal).

The third component in the LCC equation is the discount rate, defined by Life Cycle Costing for Design Professionals, 2nd Edition, as “the rate of interest reflecting the investor’s time value of money“. Basically, it is the interest rate that would make an investor indifferent as to whether he received a payment now or a greater payment at some time in the future (LCCA Handbook, 1999; Kilyeni S. et al.**,** 2010).

It must be separated into two types: real discount rates and nominal discount rates. The difference between the two is that the **real discount rate** *excludes* the rate of inflation and the **nominal discount rate** *includes* the rate of inflation. This is not to say that real discount rates ignore inflation, their use simply eliminates the complexity of accounting for inflation within the present value equation. The use of either discount rate in its corresponding present value calculation derives the same result. For simplicity, this handbook will focus on the use of real discount rates in the calculation of LCC for project alternatives.

Obviously, as the economics of the world around us change, so to does the discount rate. To establish a standard discount rate to be used in LCCA, will be adopted the official National Bank’s real discount rate. The rate will also be updated annually in the LCC’s spreadsheet tool, according that available on the National Bank’s web site.

RESULTS AND DISCUSSION

After the complete analyze was created a generalized model for LCCA - inputs-outputs generalized model for culture exploitation (figure 1).

Such generalized models present an integrated systemic approach which considers all types of inputs (material, information, energy, equipment and natural) and different types of outputs (raw materials products, pollutants etc.). The application was in three dimensions: one in inputs and outputs, other regarding tot the cost of each phase of the model (P1-P7) and the third in product life cycle (concept formulation, concept validation, development, production, operations and land removal). The final objective was to decide in optimum conditions on the acquisition of equipment for willow culture.

The model presented in figure 1 excludes the cost corresponding to the level of concept formulation and concept validation, because such costs in the case of willow plantation are insignificantly than costs for development, production, operations and culture’s removal, where the cost for equipment acquisition is essential.

Special objectives were conducted for compare differences between costs for different equipment and tractors.

For analyzed scenarios, firstly were considered equipment presented at paragraph 2.1 and different growing area: 10 ha, 20 ha and 100 ha.

An EXCELL application program was used for calculus in next conditions: discounted rate 12%, yearly incomes per ha - starting from second year - 1200 EUR, all other costs per ha used data from Tucu D., Hollerbach W., 2011, cycle duration 25 year (plus year “0”, for preparing before plantation), no consideration of financial risk.

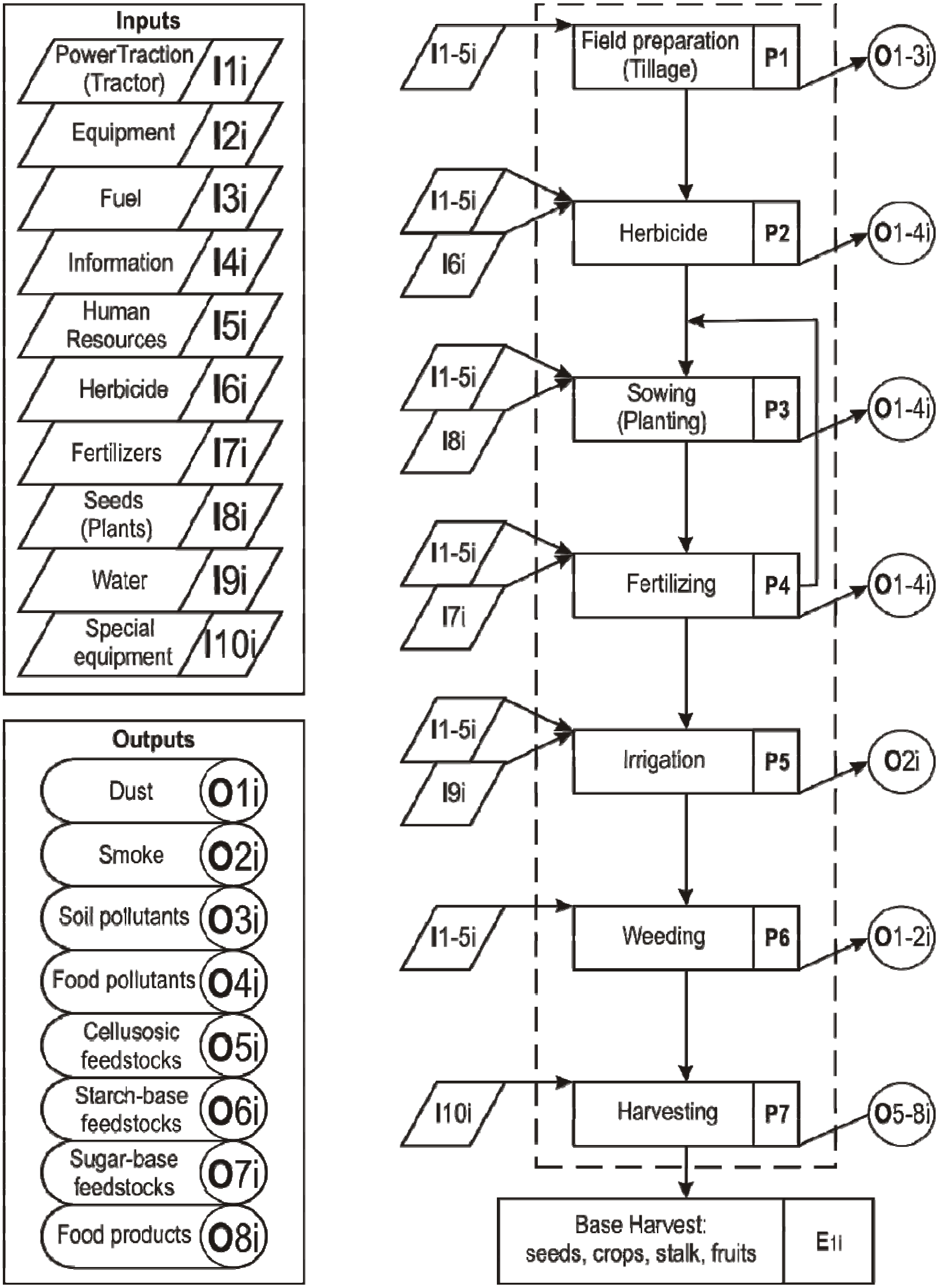

Fig.1 Inputs-outputs generalized model for culture exploitation

Table 1 presents the results of absolute value, and discounted value for both three scenarios, corresponding to different values for equipment investments.

Table 1 Results of life-cycle cost analysis

Equipment's value	Area					
	10 ha		20 ha		100 ha	
	Absolute Value	Discounted value	Absolute Value	Discounted value	Absolute Value	Discounted value
10000	194250	53992	398500	111120	2032500	568151
50000	154250	41443	358500	98571	1992500	555602
100000	104250	25756	308500	82885	1942500	539916
150000	54250	10070	258500	67199	1892500	524230
200000	4250	-5616	208500	51513	1842500	508544
250000	-45750	-21303	158500	35826	1792500	492857
300000	-95750	-36989	108500	20140	1742500	477171
350000	-145750	-52675	58500	4454	1692500	461485
400000	-195750	-68361	8500	-11232	1642500	445798
450000	-245750	-84048	-41500	-26919	1592500	430112
500000	-295750	-99734	-91500	-42605	1542500	414426

The final resulted costs by application such generalized models for willow culture confirms important results:

- The optimum solution for willow culture exploitation and equipment acquisition must consider the growing area. Three relevant situations were considered: 10 ha, 20 ha and 100 ha.
- For 10 ha and 20 ha is optimum the use of external services for equipment for mechanization. If the owner has other business in agriculture, an important part of equipment can be used both for willow culture (176.6 kW tractor, subsoiler, different harrows, equipments for tilling, culture's maintenance, transportation etc.), not more than 100000 EUR for 10 ha growing area or not more than 300000 EUR for 20 ha growing area (it must be considered financial risk in conditions of actual world economy.
- For 100 ha exploitations it is efficient to use own agricultural machines including planting machine and self-propelled harvesting combine (this research study didn't consider the acquisition of second hand machines, but can offer practical limits).
- Another possibility could be creation of willow cultivators associations and trials to access public funds for developing futures projects in equipment acquisition. In such situation it will be necessary to use feasibility studies and business plans that consider maximum payment delay (till one year, considering the hard administrative and birocratic system of public funds and slowly ness of reimbursement process).

CONCLUSIONS

Life Cycle Cost Analysis (LCCA) is an adequate method for a system of interest (including individual agricultural systems, system of systems (agricultural associations), and production and business in agriculture equipment.

LCCA provides illustrations on the types of life cycle cost studies that can be conducted and examples to demonstrate the benefits of conducting life cycle cost to inform the decision making process regarding the acquisition of equipment.

LCCA should not be considered as a one-off task, it must be recognized as an ongoing activity throughout all stages of the life cycle in agricultural engineering, especially in equipment acquisition.

In the situation of willow culture, more variable must be considered for LCCA application: exploitation surface, equipment, costs, repair and maintenance costs, local public strategies, environmental conditions etc. It is obviously that application of LCCA for decision of equipment acquisition must be applied according to growing area, estimated incomes, taxes and cycle duration.

For 10 ha and 20 ha is optimum the use of external services for equipment for mechanization. If the owner has other business in agriculture, an important part of equipment can be used both for willow culture (tractors, subsoiler, different harrows, equipments for tilling, culture's maintenance, transportation etc.), not more than 100000 EUR for 10 ha growing area or 300000 EUR for 20 ha growing area (in condition of 1200 EUR yearly incomes per ha and optimist scenarios, minimum risks).

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Pregledni rad
Review paper

DEVELOPMENT OF A METHOD FOR ASSESSING THE PERFORMANCE OF AGRICULTURAL BIOGAS PLANTS

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SUMMARY

This paper presents a method developed for assessing the performance of agricultural biogas plants. The method is capable of handling uncertainty in the performance data as well as in the assessment itself. It provides quantitative assessment results that enable ranking of assessed biogas plants and qualitative assessment results that are used to indicate the necessity for performance improvement. Future research should be focused on developing a complementary method that provides probable reasons for poor performance, wherewith concrete measures for the performance improvement could be defined.

Key words: *assessment, method, performance, biogas plant, agriculture*

INTRODUCTION

After introduction of feed-in tariffs for electricity from Renewable Energy Sources (RES), biogas technology has experienced significant expansion in Germany and many European countries. Feed-in tariffs enable not only the use of animal excrements for anaerobic digestion (AD) but also energy crops. Consequently, biogas production and utilization have become an important branch of agriculture.

In view of the large and still increasing number of agricultural biogas installations, there is a recognized need for improving the performance of these plants. The aim is to attain the best possible performance of existing biogas plants. In order to achieve this, it is necessary to: 1) collect detailed and reliable performance data from individual biogas plants, 2) assess their performance, 3) recognize reasons for poor performance, and 4) define necessary measures to improve this.

Good performance of a biogas plant, namely its efficient operation, may be defined as follows: 1) Technical, biological and chemical conditions are optimized in order to maximize biogas production rate; 2) the plant is operated efficiently in terms of energy utilization; 3) mitigation of environmental pollution is maximized; and 4) operation of the plant is profitable for the owner. Based on this definition, the performance of an agricultural biogas plant may be described by various performance figures (Effenberger *et al.*, 2009b).

So far, several projects have been carried out to monitor biogas plants and collect performance data under practical conditions (Schöftner *et al.*, 2006; Effenberger *et al.*, 2009a; Anonymous, 2009). Numerous performance figures were defined as well, in order to unambiguously describe the performance of monitored biogas plants (Strobl & Keymer, 2006; Effenberger *et al.*, 2009b). Attempts were also made to assess and compare the performance of these plants with multi criteria methods (Braun *et al.*, 2007; Madlener *et al.*, 2009; Djatkov & Effenberger, 2010). Only few assessment approaches are established on expertise in the field of biogas technology (Djatkov *et al.*, 2009; Effenberger & Djatkov, 2011). Still, even these approaches are not reliable enough since the obtained results could not be interpreted by experts. As a consequence, neither reasons for poor performance could be recognized, nor measures for the performance improvement could be defined.

The objective of this paper is to present the method that has been developed for assessing the performance of agricultural biogas plants. The method was tested using performance data of ten Bavarian agricultural biogas plants. A further objective is to present assessment results and to propose how these results could be used for improving the performance of biogas plants.

MATERIALS AND METHODS

Assessed biogas plants

In this study, assessment has been conducted using performance data of ten Bavarian agricultural biogas plants monitored over a period of two years. More detailed description of these plants and monitoring results can be found in Effenberger *et al.* (2009a) and Effenberger & Djatkov (2011).

Eight pertinent performance figures are selected to be used as assessment criteria (C1-C8, Tab. 1). These are described in detail in Effenberger & Djatkov (2011) and Djatkov *et al.* (2012) and their values are presented in Tab. 2.

Error propagation

In science and engineering, measured parameters inevitably contain errors in their values. These errors do not subsume mistakes in measurement. Deviation from the exact value exists due to imprecision of a measuring device. Expected deviations are mostly known and specified by the manufacturer of a measuring instrument (*e.g.* ± 1%). This type of uncertainty in the data is classified as a systematic error (Hoffmann, 1999).

Table 1 Selected performance criteria

Criterion	Title	Unit	Error*, %
C1	Relative biogas yield	%	8.0
C2	Methane productivity	$m^3 \cdot (m^3 \cdot d)^{-1}$	3.6
C3	Utilization ratio of CGU	%	2.0
C4	Methane utilization ratio	%	6.5
C5	Specific GHG emissions	$g\ CO_{2,eq} \cdot kWh_{el}^{-1}$	10.6
C6	Cumulated energy demand	$kWh \cdot kWh_{el}^{-1}$	16.3
C7	Profit	$€ \cdot (kW_{el} \cdot a)^{-1}$	2.0
C8	Labor input	$Lh \cdot (kW_{el} \cdot a)^{-1}$	5.0

* Overall errors in the values of assessment criteria determined by error propagation

Table 2 Criteria values used in the assessment

Plant ID	C1	C2	C3	C4	C5	C6	C7	C8
A	103	0.79	97.8	30.4	211	0.32	121	4.55
B	106	0.71	82.4	30.0	206	0.43	-449	2.24
C	126	0.78	93.7	65.2	-5	-0.22	347	2.61
D	123	0.98	79.3	49.4	129	0.02	451	1.45
E	130	0.97	97.1	49.0	-10	-0.19	487	6.62
F	84	0.76	91.3	58.2	131	-0.16	312	3.10
G	116	1.00	96.1	42.2	215	0.31	350	4.77
H	108	0.74	92.2	50.9	237	0.11	98	3.47
I	119	1.20	58.6	42.8	256	0.14	9	1.81
J	111	0.65	89.0	42.4	140	0.18	351	2.38

The assessment criteria are derived using several measured parameters. It is of interest to determine an overall error, contained in values of assessment criteria and influenced by errors of individual measured parameters. For this purpose, the principles of error propagation have been used, which fundamentals are presented by Eq. 1 and 2 (Hoffmann, 1999). Under the assumption that assessment criterion (function f) is derived from two measured parameters (x and y), an overall error (δ_f) is calculated concerning errors of individual parameters (Eq. 2). Therewith, the maximum possible error is determined. Calculated errors for the assessment criteria values are presented in Tab. 1.

$$f = f(x, y) \tag{1}$$

$$\delta_f = |\delta_{fx}| + |\delta_{fy}| = \left|\left(\frac{\partial f}{\partial x}\right)\delta_x\right| + \left|\left(\frac{\partial f}{\partial y}\right)\delta_y\right| \tag{2}$$

Theory of fuzzy logic

The theory of fuzzy logic was proposed by Zadeh (1965) and is suitably represented by fuzzy sets. Fuzzy sets have no sharp boundaries and this property allows partial membership in fuzzy sets, as opposed to exclusively no or full membership of objects in classical sets. This concept has been utilized in many engineering applications in order to model an uncertainty (Klir & Yuan, 1995). The uncertainty refers to imprecision, non-specificity, vagueness, inconsistency *etc*.

Another important concept of fuzzy logic that is commonly used is that of a linguistic variable (Klir & Yuan, 1995). This is a quantitative variable, whose classes represent fuzzy numbers with corresponding linguistic terms. Therewith, beside quantitative, a linguistic variable possesses qualitative property. In this study, each assessment criterion is a linguistic variable with efficiency classes represented by fuzzy numbers, whereby expertise from the field of biogas technology was easily embedded.

Fuzzy logic was used in this study to model uncertainty in the values of assessment criteria, determined by principles of error propagation and uncertainty in the represented knowledge, *i.e.* expertise from the field of biogas technology.

Theory of expert systems

The term expert system subsumes software that is applied to solve complex problems in a certain field (Prerau, 1990). The user supplies an expert system with facts or data and receives expertise in response. An expert system emulates human experts using their knowledge and experience to solve problems by reasoning and making of conclusions, rather than with numerical calculations.

In general, an expert system consists of a knowledge base and an inference engine (Giarratano, 1993). The knowledge base contains relevant expertise from the problem domain, whereas the inference engine applies this knowledge. In this study, the knowledge base consists of a set of IF-THEN rules used to represent relevant knowledge from the field of biogas technology. The IF part or antecedent, contains the condition of the rule. These conditions are determined by efficiency classes of performance criteria. The THEN part or consequent, contains the conclusion of the rule about the performance of a biogas plant. All rules are integrated in the system of approximate reasoning (Klir & Yuan, 1995), which is in fact the inference engine.

Application of the developed method

The code for assessing the performance of agricultural biogas plants was written in *Matlab* software. All applied principles and expertise are contained in the code.

RESULTS AND DISCUSSION

In this section, a comprehensive overview of the most important steps in the development and application phases of the method is presented. Finally, assessment results for ten biogas plants are shown and their application for performance improvement is discussed.

Method development

Fig. 1 depicts how the assessment problem was structured. This step in the development phase is significant, since the assessment is simplified. To assess the overall performance of a biogas plant, eight selected performance criteria were grouped, such that always two assessment criteria describe the corresponding assessment aspect. Since the technical aspect is determined by four criteria, additional simplification was achieved by considering biogas production and utilization separately. Overall performance is assessed accounting for technical, environmental and socio-economic aspects.

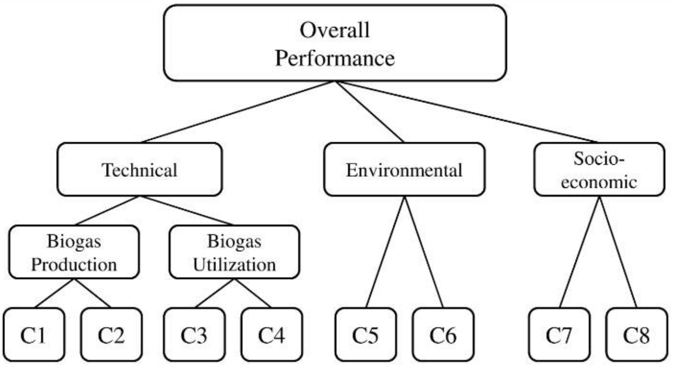

Figure 1 Problem structure in performance assessment of biogas plants

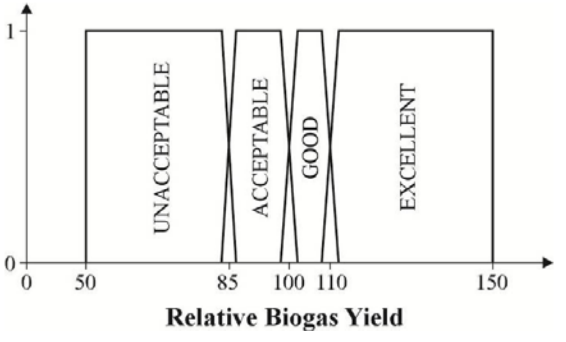

Figure 2 Efficiency classes for the performance criterion Relative Biogas Yield (C1)

Hereinafter is described a principle to define efficiency classes for assessment criteria, using example of C1 (Fig. 2). According to the values achieved in practice (Anonymous, 2009; Effenberger *et al.*, 2009a), the range of possible values of C1 was determined at first: 50 to 150%. Furthermore, four new ranges were defined using threshold values (85, 100 and 110) and qualitative meaning was assigned to these efficiency classes (UNACCEPTABLE; ACCEPTABLE; GOOD; EXCELLENT). For example, according to experts' opinion, all biogas plants with value of C1 larger than 110, are qualitatively assessed such that they belong to the efficiency class EXCELLENT. Still, even pertinent experts could not determine sharp boundaries between any of two classes. In order to model this uncertainty, fuzzy numbers, *i.e.* fuzzy efficiency classes are constructed from these ranges by using fuzzy distances of 2.

Since for each assessment criterion four efficiency classes are determined, there are 16 plausible rules needed to assess each aspect. An additional 16 rules are needed to assess biogas production and biogas utilization. Finally, another 64 rules are required to assess the overall performance with respect to technical, environmental and socio-economic aspects. Therefore, 144 rules in total are defined in order to assess the overall performance of a biogas plant and its different aspects (4x16+16+64=144, see problem structure in Fig. 1). Tab. 3 presents rules that were defined by experts for assessing the aspect of biogas production. For example, the first rule should be interpreted as follows: "If Relative Biogas Yield is EXCELLENT and Methane Productivity is EXCELLENT, then Biogas Production is EXCELLENT". In other words, if a biogas plant has a value for C1 that is qualitatively assessed EXCELLENT (see Fig. 2) and a value for C2 assessed EXCELLENT as well, according to experts' opinion the performance of Biogas Production should be assessed as EXCELLENT, qualitatively. In addition, experts defined the necessity for improving the performance (see explanation beneath Tab. 3).

Table 3 Rules for assessing Biogas Production

Rule	C1	C2	Biogas production
1	EXCELLENT	EXCELLENT	EXCELLENT
2	EXCELLENT	GOOD	EXCELLENT
3	EXCELLENT	ACCEPTABLE	GOOD
4	EXCELLENT	UNACCEPTABLE	ACCEPTABLE
5	GOOD	EXCELLENT	GOOD
6	GOOD	GOOD	GOOD
7	GOOD	ACCEPTABLE	GOOD
8	GOOD	UNACCEPTABLE	ACCEPTABLE
9	ACCEPTABLE	EXCELLENT	ACCEPTABLE
10	ACCEPTABLE	GOOD	ACCEPTABLE
11	ACCEPTABLE	ACCEPTABLE	ACCEPTABLE
12	ACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE
13	UNACCEPTABLE	EXCELLENT	UNACCEPTABLE
14	UNACCEPTABLE	GOOD	UNACCEPTABLE
15	UNACCEPTABLE	ACCEPTABLE	UNACCEPTABLE
16	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE

EXCELLENT: No improvement is practically possible.
GOOD: Improvement possible.
ACCEPTABLE: Improvement recommended.
UNACCEPTABLE: Improvement urgently necessary.

Method application

Application of the method for assessing the performance of agricultural biogas plants consists of the following steps:

1. Construction of fuzzy input values from assessment criteria values (fuzzification);
2. Checking the compatibility of fuzzy input values with fuzzy efficiency classes to derive conclusions from individual rules;
3. Aggregation of fuzzy numbers for assessment of technical, environmental and socio-economic aspects, as well as overall performance;
4. Qualitative interpretation of the assessment results by assigning them to one of the four defined fuzzy efficiency classes;
5. Ranking of assessed biogas plants by defuzzification of aggregated fuzzy numbers which are assessments of certain aspects or overall performance.

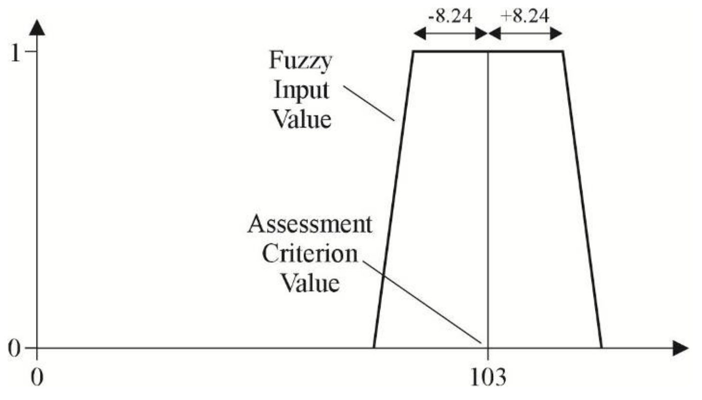

Figure 3 Fuzzified assessment criterion C1, value for biogas plant A

Fig. 3 depicts fuzzified value of assessment criterion C1. According to Tab. 1, the maximum error for C1 is 8.0%. This value is relative and for the criterion value of 103% (biogas plant A, Tab. 2) this calculates to an absolute maximum error of 8.24%. On that basis, the real value of 103% was fuzzified such that all values that deviate from 103 by ±8.24 pertain to the determined fuzzy input value with a certainty of 1. In other words, the α-cut of the presented fuzzy number, where α=1, has range [103-8.24, 103+8.24].

A procedure to assess the performance of a biogas plant by approximate reasoning is illustrated in Fig. 4. For given fuzzy input values for C1 and C2 (presented as dotted fuzzy numbers), compatibilities with all corresponding fuzzy efficiency classes in all defined rules are checked. Compatibility is in fact the height of the intersection of two fuzzy numbers, input value and efficiency class, given in Fig. 4 as straight horizontal grey line. The conclusion from each rule is truncated corresponding to the fuzzy efficiency class. The height that truncates the fuzzy efficiency class is determined by applying the *min* operator to the pair of heights for both fuzzy input values. The final conclusion is aggregated by applying the operator *sum* to all conclusions (grey fuzzy number in Fig. 4). Here, only

Rules 1 and 2 are presented, since only for these rules compatibilities exist and conclusions are derived. Consequently, only two conclusions are used to make the final conclusion, *i.e.* to assess the performance of biogas production.

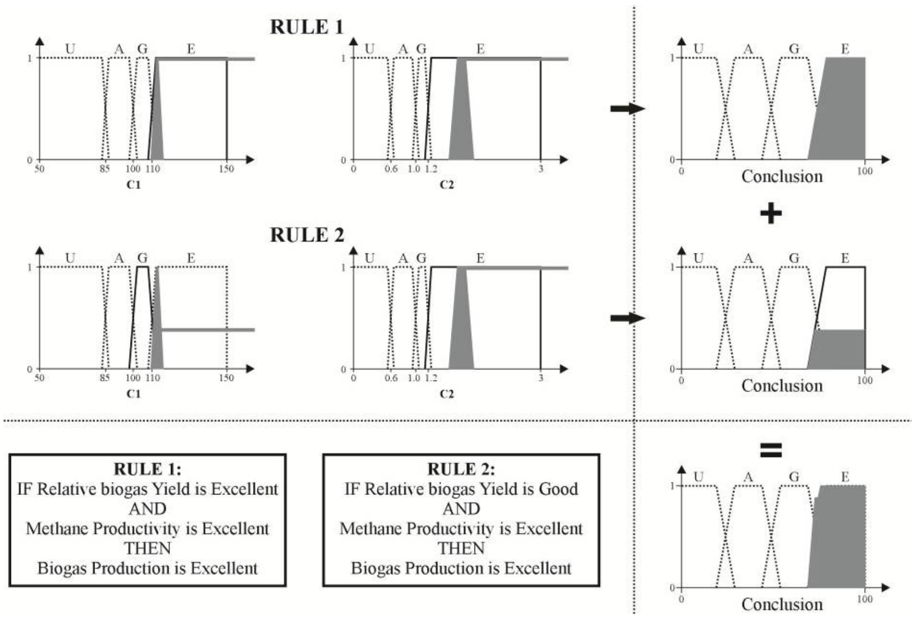

Figure 4 System of approximate reasoning to assess performance of biogas production

The next step is to assess the performance of a biogas plant in qualitative terms. From Fig. 4 it can be seen that the aggregated fuzzy number corresponds mostly to efficiency class EXCELLENT, but partly to GOOD as well. Still, it is not always simple to distinguish this, and therefore no linguistic term could be assigned to the aggregated fuzzy number, intuitively. To overcome this, the Euclidean distance between the aggregated fuzzy number (R) and each fuzzy efficiency class (S) was calculated (Eq. 3). The shortest Euclidean distance proves the greatest similarity between two fuzzy numbers. Therefore, the linguistic term of the fuzzy efficiency class with the shortest distance from the aggregated fuzzy number is to be assigned as relevant.

$$d(R,S) = \sqrt{\sum_{x=0}^{100}\left(R_{(x)} - S_{(x)}\right)^2} \tag{3}$$

In order to determine which of the biogas plants in the assessment performed better, they should be compared and ranked. Since the aggregated fuzzy numbers are rather complex, this could not be achieved by simple comparison. Therefore, to obtain real values from aggregated fuzzy numbers, the centroid defuzzification method was used (Eq. 4) which calculates the center of the area under the membership function curve. The biogas plant with a larger real value received a better ranking.

$$d(R) = \frac{\sum_{x=0}^{100} R(x) * x}{\sum_{x=0}^{100} R(x)} \tag{4}$$

Assessment results

Tab. 4 shows the results from the performance assessment of the ten biogas plants. Given are the assessments of three individual aspects, including biogas production and biogas utilization, and of overall performance. In all cases, the performance assessment (PA) is provided as a real number within the range [0, 100]. Subsequently, considering the overall performance, biogas plants are ranked appropriately. Qualitative assessment is provided by symbols in parentheses.

Table 4 Assessment and ranking of the ten biogas plants

Plant ID	Biogas production	Biogas utilization	Technical aspect	Environmental aspect	Socio-economic aspect	Overall	
						Rank	PA
A	51.25 (G)	13.71 (U)	15.22 (U)	36.94 (A)	13.01 (U)	10	13.21 (U)
B	51.55 (G)	13.01 (U)	13.71 (U)	24.92 (U)	13.81 (U)	8	15.82 (U)
C	62.46 (G)	49.95 (G)	49.95 (A)	62.46 (G)	48.55 (A)	3	47.35 (A)
D	81.38 (E)	26.23 (A)	26.23 (A)	62.46 (G)	84.68 (E)	2	50.05 (A)
E	73.67 (G)	26.23 (A)	26.23 (A)	62.46 (G)	37.54 (A)	4	37.54 (A)
F	13.71 (U)	50.05 (A)	15.21 (U)	62.46 (G)	37.54 (A)	5	37.54 (A)
G	66.47 (G)	13.71 (U)	15.12 (U)	36.44 (A)	35.44 (A)	6	31.73 (A)
H	54.45 (G)	26.23 (A)	26.23 (A)	30.53 (A)	20.22 (U)	7	26.23 (A)
I	37.54 (A)	12.51 (U)	12.51 (U)	26.23 (A)	12.51 (U)	9	13.71 (U)
J	48.65 (G)	13.71 (U)	15.21 (U)	62.46 (G)	56.16 (A)	1	50.15 (G)

PA: Performance Assessment; E: Excellent; G: Good; A: Acceptable; U: Unacceptable.

The qualitative assessments obtained indicate where the operator of a biogas plant could start to improve the performance of his installation. For example, if overall performance is assessed as ACCEPTABLE, the performance of this biogas plant should be improved (as stated in Tab. 3). Furthermore, the performance of each aspect may be considered. For example, aspects of technical, environmental and economic performance are assessed as UNACCEPTABLE, GOOD and ACCEPTABLE, respectively. It can be concluded that improvement of technical aspect is urgently necessary. Therefore, an operator could use these results in order to recognize where he could start with the performance improvement of own biogas plant.

Compared to previous assessment approaches (Braun *et al.*, 2007; Madlener *et al.*, 2009; Djatkov *et al.*, 2009; Djatkov & Effenberger, 2010; Djatkov *et al.*, 2012), the method presented in this work has the following advantages. Firstly, it enables an absolute assessment, *i.e.* each biogas plant is always assessed with respect to predefined conditions presented by efficiency classes, but not just in relation to other plants. Therewith, even a single biogas plant could be assessed. Unlike methods in Djatkov *et al.* (2009) and Djatkov *et al.* (2012), this method overcomes the problem of compensation between criteria in the overall assessment by the application of rules. Moreover, the reliability of the assessment results is improved by including pertinent expertise which was a particular shortcoming of previous methods (*e.g.*, Madlener *et al.*, 2009 and Djatkov & Effenberger, 2010).

CONCLUSIONS AND OUTLOOK

The performance of a biogas plant may be described by numerous characteristic figures. Consequently, the assessment of biogas plant performance seems to be a complex and demanding task, even for pertinent experts. Therefore, a method for performance assessment of agricultural biogas plants has been developed and is presented in this paper. The method is capable of handling two main problems when assessing the performance of biogas plants. These are uncertainties in the performance data and in the assessment itself. For this purpose, the theories of fuzzy logic and expert systems were used. A number of disadvantages of previously applied assessment approaches were overcome. Most importantly, the method contains expert knowledge from the field of biogas technology. Therefore, we propose that this method may be used by experts and plant operators as a tool to obtain quick, reliable and consistent assessment results. Also, the method indicates the necessity for improvement of biogas plant performance. In this stage of the method development, concrete actions in order to improve the performance of individual plants remain unknown. Future research should be focused on developing a complementary method that allows for identifying probable reasons for poor performance.

ACKNOWLEDGEMENT

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Origionalni znanstveni rad
Original scientific paper

INTRODUCTION TO THE GREENHOUSE DECISION SUPPORT MODEL

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SUMMARY

In this paper an introduction to a model that can serve for optimal choice of the greenhouse technical and technology system is presented. The model is very suitable for producers to whom adequate solution of the greenhouse production systems can be suggested, based on their elementary idea, regarding the greenhouse construction type and technical systems with their capacities. Based the chosen plant production and available production area the model suggests to the farmer which type of greenhouse to use, which technical systems together with their capacity and suggests the area for further expansion.

Key words: *greenhouse, model, algorithm, technical systems.*

INTRODUCTION

Concerning the growth of human population, global climate change and economical crises, there is a need for constant increasing of food production. One way to intensify the vegetable production was introduced during the fifties in the 20th century, know as greenhouse production. Since that period researchers are working on new covering materials, new constructions and new production systems in order to have more energy and ecology efficient plant production. The theories of "high yield" in last century led to intensive energy consumption through the fertilizers, plant protection chemicals and heating energy. In this way higher yield were obtained but for what price? Energy consumption was much higher while ecology aspect of the production was led to question because of intensive use of agro-chemicals. These two led to the economy analysis which is still the main question in the greenhouse production.

In all these innovations and economy questions ordinary agricultural producer, when trying to start these king of production, if not guided well can easily give up the idea.

Greenhouse production is a production system that needs a good management. If on the beginning things are not clear to the producer than greenhouse system won't work properly and it would economically be unstable. At present, in Serbia region, for starting a greenhouse production, a farmer can contact people from the Faculties of Agriculture, but more often they consult the equipment trading companies. This may have good sides as well as bad sides. Before going for any consultation it would be easier for the farmer to have an idea what he wants, what is he capable of and what are his resources. This was the main motivation for the work presented in this paper. A simple model as decision support model for the greenhouse production system was made that should be able to give a start-up idea for any producer that whishes to start this serious business. For using this model farmer must have a PC computer and Microsoft Excel software installed. In this paper main structure of the model is presented and main decision points analyzed.

In the past, lot of research has been done concerning the modeling of the greenhouse production system and processes. Most important was to define the factors that define and determined one well balanced greenhouse production system. Factor proposed by Stevens et al (1994) are market, motivation, previous experience, location etc. If all these conditions are well balanced than further steps of establishing depend on the chosen fruit/vegetable, available surface, production season, soil quality and parcel orientation. These parameters can give a good orientation to the farmers in sense which technical systems he needs to use and to give their preliminary capacities. Martinov et al (2006) give the flow diagram for the establishing of greenhouse system. In the diagram, they included all activities, documents and decisions that are needed for the greenhouse project realization. The structure of the diagram is prepared with the help of national and international standards. An example of how Microsoft Excel software can be used as a tool for making a model and for its verifications is presented by Tanasć (2006). He concluded that the model can be very simple and very easy for use by those who have a PC computer. An interesting example or, better say questionnaire, was presented by NAAN Corporation (Naandanjain, 2009). The questionnaire has two parts and it can be filled on-line. First part is about the geographical and location data, together with climatic data. The second part is about whether are you planning a new greenhouse or you are doing the reparation.

MATERIAL AND METHOD

For the model preparation few main questions are used as its base. First group of questions was based on the chosen fruit / vegetable production and production surface that is on disposal. These questions are used in model for formulating the greenhouse type of construction, its dimensions and orientation. Second group of question was based on production technology, the time of harvesting and soil quality. These questions are used in model to give an answer about the time of planting and the production technology that should be applied. Third group of questions is based on construction, covering material, production technology and give the answers about the technical systems and their capacity. Forth group of questions is based on the production area and give an answer about the additional surface for the storages, protective areas, parking areas etc. All these questions served as a formatting tool for the model algorithm.

Based on all these input parameters, and obtained output parameters, the model gives a final report with the exact data about the greenhouse type of construction, covering material, orientation, production are, time of planting, production technology, type of ventilation system and its capacity, type of heating system and its capacity, type of irrigation system and its capacity as well as additional operational surface and protective areas.

For the easier determination of the greenhouse type and dimensions an additional date base in Excel was made that consists of all available types of greenhouse construction available in Serbia region and their available dimensions (Fig. 1).

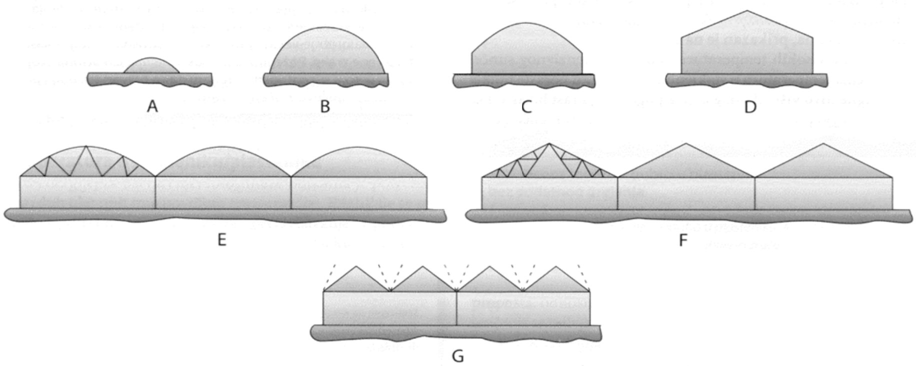

Figure 1 Type of greenhouse construction included in the model (A – low tunnel, B – high tunnel, C and D – single greenhouses, E, F, G – multi-span greenhouses) (Martinov et al, 2006)

For the orientation and greenhouse type of construction model uses common recommendations given by the international standards (Nelson, 2003).

For the purpose of production technology determination another database that consists of the planting / harvesting dates for the moment most common vegetables, was made (Momirović, 2003). In this part of the model a database of the soil properties that would be optimal for the production (Momirović, 2003) was made and inserted to Excel.

Concerning the part about the choice of technical systems, standards about the ventilation rate (Nelson, 2003, Willits, 1993) were entered in the model. For the purposes of heating systems calculation, date base about the covering materials, wind speeds and type of the heating systems was made and incorporated in the model (Nelson, 2003, Martionv et al, 2006). For easier calculation of the irrigation system capacity a date bas about the currently available irrigation systems, suitable for the greenhouse production was made (Bajkin et al, 2005). This data base includes the type of irrigation system and their technical specifications.

For the last, organizational part of the greenhouse model standards for the additional surface for storages, working space, parking space and security zones are inserted (Hanan, 1998, Nelson, 2003).

RESULTS AND DISCUSSION

Based on the parameters given above, an algorithm was made. One part of it is represented in the Figure 2. This part of the algorithm, based on the inserted culture and the desired production surface suggests the type of greenhouse construction. Model "leads" the user to the date base about the types of greenhouse construction where he chooses one type and its dimensions. Based on the parameters that were chosen by the user, model suggests orientation, calculates production surface and gives the covering material / production surface ratio that is needed for further steps in the model.

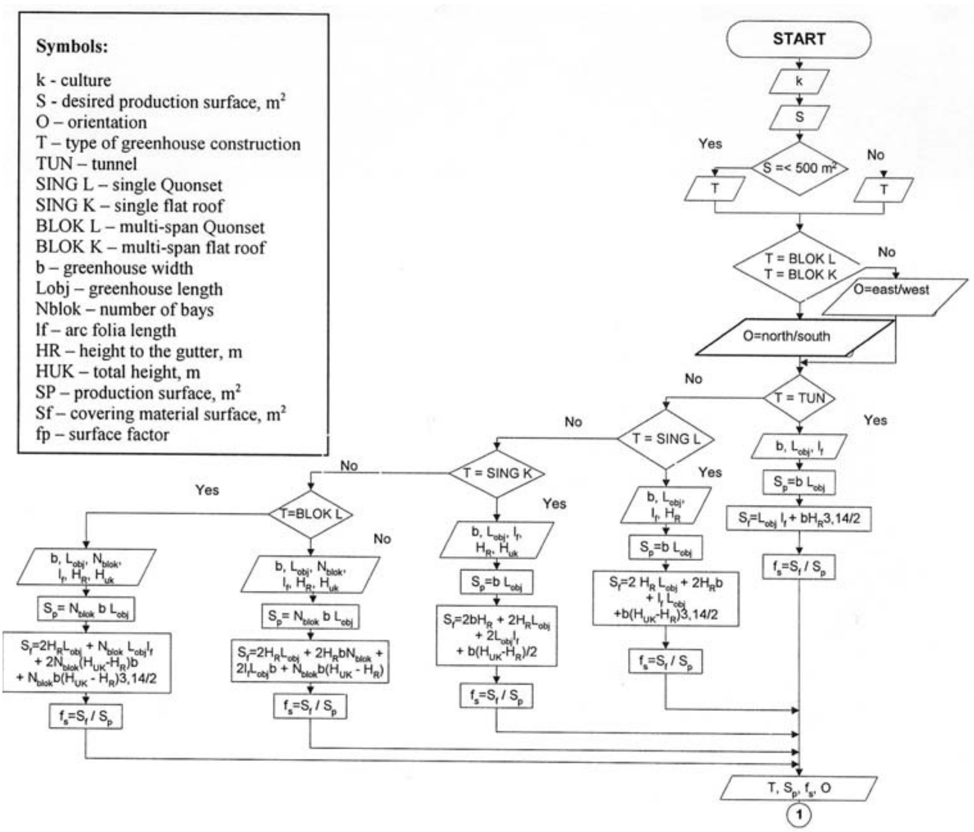

Fig. 2 Part of the algorithm that chooses greenhouse type of construction, dimensions and production surface

Further part of the algorithm represents the part of choosing the production season and technology. User is asked about the time of harvesting and about the basic parameters of the soil quality (organic matter content, levels of nitrogen, phosphorus and potassium and pH level). Analyzing the user answers model suggests the time of planting and the production technology (Fig. 3).

Fig. 3 Input and output parameters for the production technology suggestion

In Figure 4, input and output variables for the optimization of the ventilation system are presented.

Fig. 4 Input and output variables for the ventilation system suggestion

In this case model already has the needed values so this parameters is automatically calculated when construction, dimensions and surface of ventilation openings are known. The final output will be given through the capacity of a single fan (m^3/min) and their total number in the greenhouse.

In case of heating model suggests whether heating is needed or not. The input variables are already known except that the user must suggest what covering material will be used, predicted wind speed in the area and what king of heating system does he want (air heating, pipe central heating, etc.).

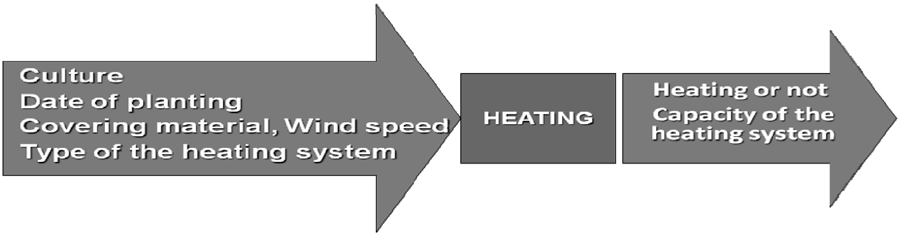

Fig. 5 Input and output variables for the heating system suggestion

Final output will be given through the heat losses of the greenhouse (kW).

Concerning the irrigation system, model already has some values. User must decide about the type of system (model suggests him concerning the plant production). After choosing the type user must decide how many irrigation cycles per day he wants.

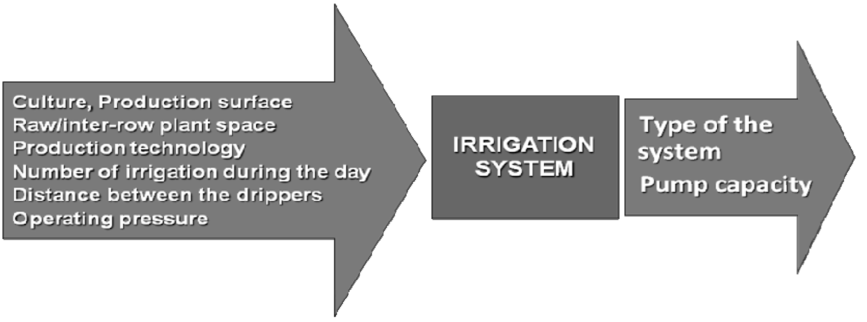

Fig. 6 Input and output variables for the irrigation system suggestion

The output of this step is what type of system did the user choose, what is the capacity of the system and of the pump and how much water per cycle does he need.

Final step in the proposed model is to suggest what is the surface needed for the storages, working offices, protective area etc (Fig. 7).

Fig. 7 Input and output variables for the additional working area

In this phase user must give the data whether or not there is some working area around the future greenhouse and what the surface. Model compares to the standard recommendations about the surface of this area an suggests whether user must prepare totally new area or only to plan some more space.

The algorithm was realized with the help of Microsoft Excel 2000 in the case of the lettuce production, tunnel greenhouse, adequate soil quality and 10 m^2 of the working (operational) area. Figure 8. presents a Final report.

So far this model is still "under construction". For this purposes only lettuce and tomato were introduced to the algorithm. So, one of the further improvement of the model will have to be introducing more vegetable and fruit species. Next thing is that there are some new types of greenhouse covering materials as well as new designs and dimensions. All these must be included in the data base. The area about the production technology must be widened by further explanation of the substrate production and soilless cultures. Some changes should be made in the sense of irrigation concerning the number and length of irrigation cycles.

FINAL REPORT	
Culture	Lettuce
Type of greenhouse	Tunnel
Tunnel width, m	10
Tunnel lenght, m	20
Orientation	East-west
Number of plants	3000-5000
Time of planting (month)	12.
Production technology	In the soil
Ventilation system	Natural ventilation
Capacity, m^3/min	
Fan capacity, m^3/min	
Number of fans in greenhouse	
Heat losess, kW	2541.82
Type of heating system	Central heating
Type of irrigation system	Micro-irigation, irigation tape
Total amount of water per day, l	1531.91
Total amount of water per cycle, l	1531.91
Number of cycles	1
Duration of cycle, h	0,5
Duration of irrigation, h	0,5
Pump, kW	0.34
Total greenhouse surfacewith working area, m^2	671.96
Surface of working area, m^2	10
Working area needs, m^2	30
Working area to built, m^2	20

Fig. 8 A final report of the model

During the algorithm implementation Excel program was found very difficult for using as a programming program. Based on the algorithm some other program must be use in order to adequately follow all parts of the algorithm. One of these can be Quick Basic or something similar.

CONCLUSIONS

Greenhouse production is a very complex production system that needs to be maintained well with great attention. Decision about starting this kind of business involves great number variables that need to be analyzed.

In this paper a simple model that is meant to be used by the ordinary farmers is presented. The model is still in the developing stage and lot of improvements are needed but the possibilities of its use are wide. The aim was to closer the greenhouse production system to a farmer by letting him to know on what parameters he can influence and how changing the one parameter can influence the establishment of whole system. Proposed algorithm was realized in the MS Excel 2000 Program but during the realization some difficulties occurred that indicate that some other program, more suitable for programming should be used.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Originalni znanstveni rad
Original scientific paper

DYNAMICS OF HEAT EXCHANGE IN STRAWBERRIES IN AN OPEN FIELD AT NIGHT-FROST CONDITIONS

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SUMMARY

Protecting strawberry plants against low temperatures must be considered in plantation equipment planning. Typically, the plants must be protected at "radiation" frost conditions when the skies are clear. This can occur in spring or fall. In this paper, we model the dynamics of heat exchange of strawberries at night frost conditions in an open field, and create a control algorithm for frost protection sprinkler systems. The algorithm takes account of air temperature, humidity, and both the convective and radiation heat loss intensity. The algorithm increases the degree to which plants are protected against frost and reduces the amount of water needed.

Key words: *freezing avoidance, night-frost, dynamics of heat exchange, control algorithm*

INTRODUCTION

The relative humidity of air is low before night frost and therefore the transparency of atmosphere for infrared radiation increases. At these conditions, the infrared radiation incident on earth is reduced and the net radiation is directed upward. As a result, the heat balance of ground surface becomes negative; the temperature of ground surface decreases and the ground will be covered by hoarfrost. During water vapour condensation the latent heat will be passed to the ground surface and rhizomes of strawberries, depending on whether condensation occurred on the former or the latter. This phenomenon decreases the speed of temperature fall in two different ways. First, ground surface and rhizomes of strawberries are affected by the latent heat of water vapour, and second, heat transfer reduces because surfaces are covered by hoarfrost.

In the course of this process, the temperature of strawberries rhizomes may fall so low that the buds are damaged. In order to avoid this, plants are sprayed with water. This method has been used for a long time but it has drawbacks. Namely, the current technology deploys intensive spraying with water which results in reduction of surface quality since nutrients are washed into the ground and the soil structure deteriorates. For this reason, in this paper we seek ways to protect plants by reducing the intensity of spraying.

MATERIALS AND METHODS

It has been explore the heat balance of the rhizome of strawberry that has no leaves. In the pre-frost period, this type of plant displays the worst case scenario. Its temperature drops fastest at night-frost because lack of leaves means heat exchange will be more rapid than in the case of leaves.

To analyse this situation, we create a model that describes the balance of heat exchange for a plant with no leaves. The model is based on the laws of heat transfer—the relationships that characterize wet air—and the computations are done using Scicoslab. The main equation we use is as follows,

$$dQ = A(R_{Ln} + R_{Sn} + P_{cnv} + P_{cnd} + P_L)d\tau, \quad (1)$$

where

A is the top surface area of the rhizome, m^2,

dQ is heat stored in rhizome (left rhizome) during time period $d\tau$, J,

R_{Ln} is heat flux density in the long wave infrared spectrum in time period $d\tau$ from the top surface of rhizome, $W\cdot m^{-2}$,

R_{Sn} is the solar energy absorbed by the top surface of the rhizome in time period $d\tau$, $W\cdot m^{-2}$,

R_{cnv} is the heat flux density between rhizomes and air, transmitted through air by convection, in time period $d\tau$, $W\cdot m^{-2}$,

R_{cnd} is the heat flux density between rhizomes and ground, transmitted by conduction, in time period $d\tau$, $W\cdot m^{-2}$,

P_L is heat flux density due to thermal condensation of moisture in time period $d\tau$, $W\cdot m^{-2}$.

R_{Ln} is given by [1],

$$R_{Ln} = -f\varepsilon_0\sigma T^4, \quad (2)$$

where

$f = (1.35R_{Sd}/R_{S0}) - 0.35$, is a function that accounts for daytime cloudiness. The minimum value $f = 0.055$ corresponds to completely overcast skies (i. e. $R_{Sd}/R_{S0} = 0.3$), and the maximum value $f = 1.0$ for completely clear skies.

R_{Sd} is measured total solar radiation, $W\cdot m^{-2}$,

R_{S0} is clear skies solar radiation, $W\cdot m^{-2}$,

ε_0 is apparent net emissivity between the surface and the skies, estimated using the expression

$$\varepsilon_0 = 0.34 - 0.139\sqrt{e_d}, \tag{3}$$

where

e_d is actual vapour pressure (kPa) measured in a standard weather shelter,

$\sigma = 5.67 \cdot 10^{-8}$is Stefan–Boltzmann constant, $W \cdot m^{-2} \cdot K^{-4}$,

T is the absolute temperature of rhizome, K.

R_{Sn} is given by [1],

$$R_{Sn} = (1 - \alpha)R_{Sd}, \tag{4}$$

where α is the fraction of short wave radiation that is radiated from a surface called albedo.

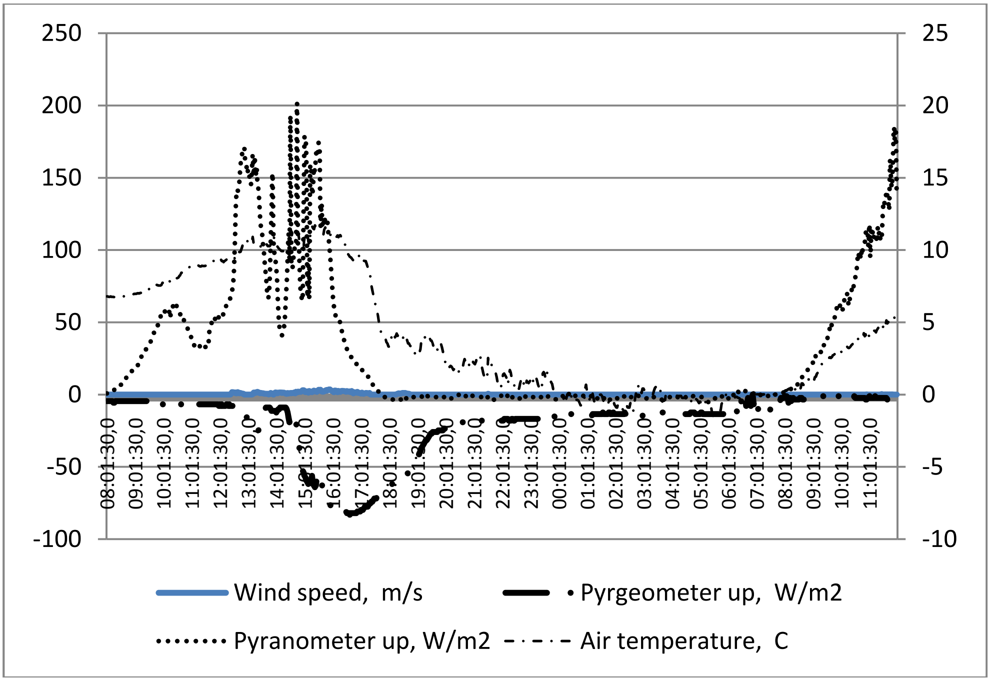

Figure 1 Measured values of wind speed, density of escaping infrared flux (by pyrgeometer), solar flux density (by pyranometer) and air temperature (values on the right axes)

The radiation heat exchange involves both the solar radiation that heats the surface of the rhizome and the heat flux that leaves the rhizome. It has been argued in [1] that "depending on the temperature and humidity, R_{Ln} on a radiation frost night typically varies between −73 and −95 $W \cdot m^{-2}$. When skies are completely overcast, R_{Ln} depends on the cloud base temperature; but $R_{Ln} = -10\ W \cdot m^{-2}$ is expected for low, stratus-type clouds. Therefore, depending on cloud cover, $-95 W \cdot m^{-2} < R_{Ln} < -10\ W \cdot m^{-2}$, with a typical value around −80 $W \cdot m^{-2}$ for a clear frost night".

The values we measured for the density of escaping infrared flux (see Fig. 1) stayed in the limits described above.

Convective heat exchange occurs between air and the top surface of the rhizome. The temperature of rhizome rises above the air temperature during daytime due to absorption of solar radiation. During frost, the temperature of the rhizome drops below the ambient temperature.

P_{cnv} is given by the expression,

$$P_{cnv} = hA\Delta T, \tag{5}$$

where

P_{cnv} is heat flow of input or lost heat flow, $J \cdot s^{-1} = W$,

H is heat transfer coefficient, $W \cdot m^{-2} \cdot K^{-1}$,

A is surface area of heat transfer, m^2,

ΔT is the difference in temperature between the solid surface and the surrounding fluid area, K.

We determine the convective heat transfer coefficient from the formulas for the Nusselt number in case of free convection from horizontal plates [2].

For the top surface of a hot object in a colder environment or bottom surface of a cold object in a hotter environment [2, p. 496],

$$\mathrm{Nu}_L = 0.54\mathrm{Ra}_L^{0.25} \text{ if } 10^4 \le \mathrm{Ra}_L \le 10^7 \tag{6}$$

$$\mathrm{Nu}_L = 0.15\mathrm{Ra}_L^{0.33} \text{ if } 10^7 \le \mathrm{Ra}_L \le 10^{11} \tag{7}$$

For the bottom surface of a hot object in a colder environment or top surface of a cold object in a hotter environment [2, p. 496]

$$\mathrm{Nu}_L = 0.27\mathrm{Ra}_L^{0.25} \text{ if } 10^5 \le \mathrm{Ra}_L \le 10^{10} \tag{8}$$

where Ra is Rayleigh number, which describes the relationship between buoyancy and viscosity within a fluid.

$$\mathrm{Ra} = \mathrm{GrPr} = \frac{g\beta}{\nu\alpha}(T_s - T_\infty)x^3 \tag{9}$$

where

$g = 9.81$ is gravitational acceleration, $\mathrm{m \cdot s^{-2}}$,

$\beta = \frac{1}{T_\infty}$, volume expansion coefficient, $\mathrm{K^{-1}}$;

v is kinematic viscosity, $\mathrm{m^2 \cdot s^{-1}}$, $v = \mu/\rho$, with μ dynamics viscosity, Pa·s, for air at 291 K 18.27 µPa·s, at 273 K 17.4 µPa·s, ρ is fluid density, $\mathrm{kg \cdot m^{-3}}$,

α is thermal diffusivity, $\mathrm{m^2 \cdot s^{-1}}$ (thermal diffusivity of air at 1 atm, 300K is $2.2160 \cdot 10^{-5}$),

T_s is surface temperature (temperature of the wall),

$T\infty$ is quiescent temperature (fluid temperature far from the surface of the object),

x is characteristic length (in this case, the distance from the leading edge).

Thermal heat transfer occurs inside the rhizome and between the rhizome and the ground. For many simple applications, Fourier's law is used in its one-dimensional form. In the x-direction,

$$q_x = -k\frac{\mathrm{d}T}{\mathrm{d}x}\,, \tag{10}$$

where

k is conductivity of material, $\mathrm{W \cdot m^{-1} \cdot K^{-1}}$,

dT is the temperature difference between the ends.

The heat flow rate for a homogeneous material with 1D geometry with constant temperature distribution between two endpoints is given by

$$\frac{\Delta Q}{\Delta T} = -kA\frac{\Delta T}{\Delta x}\,,\ \mathrm{W} \tag{11}$$

where

A is the cross-sectional surface area, $\mathrm{m^2}$,

ΔT is the temperature difference between the endpoints, K,

Δx is the distance between the endpoints, m.

At frost, the surface temperature of the rhizome drops below air temperature because of radiative heat exchange. Moisture condensates on the surface of rhizome if the surface temperature of rhizome falls below the dew point temperature. The heat flux density $\mathrm{W \cdot m^{-2}}$ transmitted to the surface of rhizome related to condensation of moisture from the air, can be determined by the latent heat transfer formulas.

The dew-point temperature is given by [3],

$$T_d = \frac{243.5 \ln(e/6.112)}{17.67 - \ln(e/6.112)}, \text{°C} \tag{12}$$

where e is the actual water vapour pressure, in units of mbar. The e may be calculated using

$$e = 0.01 \cdot RH \cdot e_s , \tag{13}$$

where

RH is relative humidity of air, %,

e_S is saturated vapour pressure, mbar or hPa.

e_S can be calculated using expression

$$e_s = 6.112 \cdot \exp\left(\frac{17.67 \cdot T}{T + 243.5}\right), \text{mbar} \tag{14}$$

where

T is temperature of air, °C.

The latent heat of condensation of water L_{water} in the temperature range from40 °C to 40 °C is approximated by the following empirical cubic function [4],

$$L_{water}(t) = -0.0000614342t^3 + 0.00158927t^2 - 2.36418t + 2500.79, \text{kJ·kg}^{-1} \tag{15}$$

with a determination coefficient R^2 = 0.999988, where t is in °C.

We have used formulas given above to create a model that simulates heat exchange processes for the rhizome of a strawberry in an open field. The rhizome is approximated by a cylinder of 3 cm with the thermal parameters of a strawberry plant. The top of the cylinder is 8 mm above the ground and 40 mm underground. The top 8 mm is divided into 4 slices of equal length, each 2 mm. The underground part is divided into two slices—the upper part is 6 mm and the lower one is 34 mm. The most critical point is about 3 mm below the upper surface, in the second slice. This is where the growth buds are located; they are sensitive to low temperatures. The model allows to examine the timeline of the temperature change in every part of the rhizome depending on the dynamics of solar radiation, density of escaping infrared flux and the presence of the frost layer.

RESULTS AND DISCUSSION

The model simulates conditions that are extremely difficult for the plants: clear skies at daytime and the intensity of solar radiation at noon up to 550 W/m2, and then clear skies at night with transparent atmosphere where the plants are in radiative heat exchange with a layer of air of -50 C. In the first case (Fig. 2) of light air convection, the temperature of the rhizome top fell below the freezing point in ~17 min. after sunset, then there was hoarfrost which stopped the decrease of the temperature of the rhizome. On the other hand, the temperature of the surface of hoarfrost fell quickly to –12 °C (with the density of the radiation flux escaping plants up to –175 W/m^2). When the skies got covered by light clouds, the temperature of the air layer rose from –50 °C to –30 °C, with the temperature of the surface of hoarfrost rising to–-6 °C and the density of escaping radiation flux decreasing to –95 W/m^2.

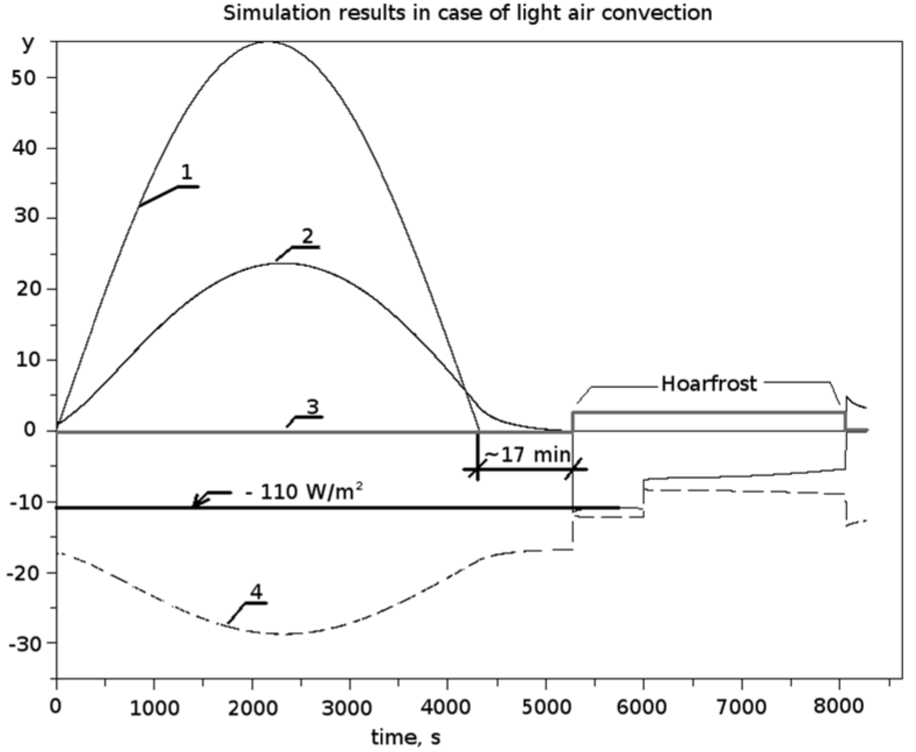

Figure 2 Simulation results in case of light air convection. 1 – Change of the intensity of solar radiation (divided by10), W/m^2. 2 – Temperature of the rhizome or the top surface of hoarfrost, °C. 3 – Thickness of hoarfrost layer (multiplied by 10), mm. 4 – Density of the heat flux escaping from the surface of the rhizome or hoarfrost (divided by10), W/m^2

In the second case (Fig. 3), there was no wind. Heat exchange between the environment and the top surface of rhizome occurred only via radiation. At noon, the temperature of the rhizome surface rose to 27 °C. In about 12 min. after sunset, the temperature of the rhizome surface fell below the freezing point and immediately it was covered by hoarfrost. The surface of hoarfrost fell quickly below -13 °C and the intensity of escaping heat flux decreased to 130 W/m^2. When the skies got covered by light clouds, the temperature of hoarfrost rose up to -7 °C, and the intensity of escaping heat flux decreased to -84 W/m^2.

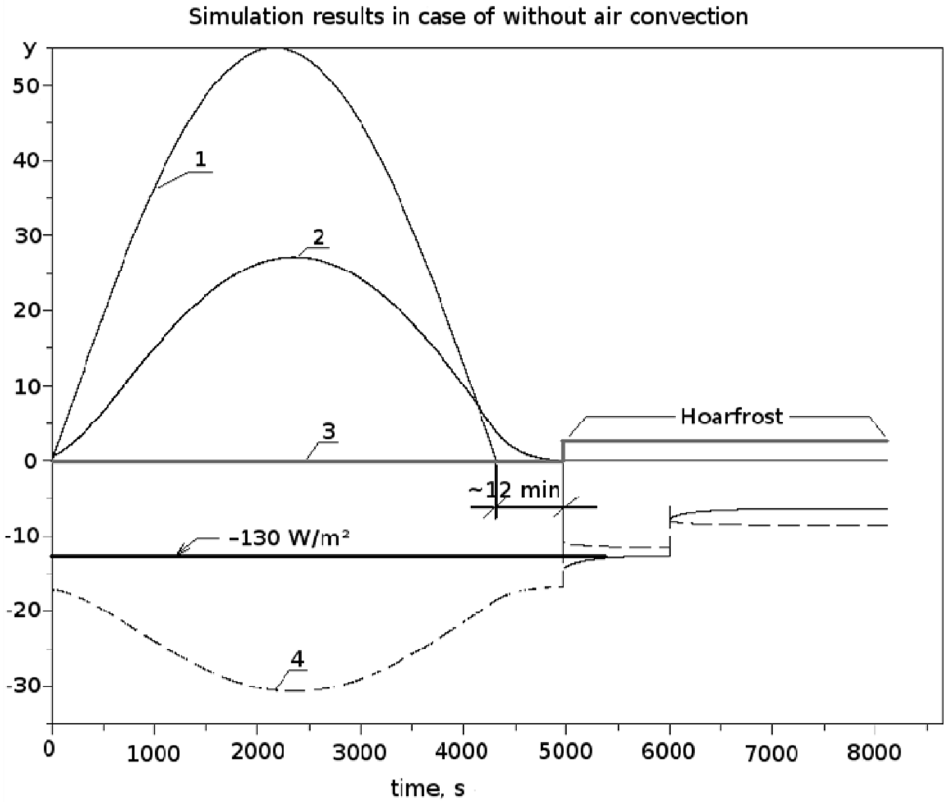

Figure 3 Simulation results in case of without air convection. 1 – Change of the intensity of solar radiation (divided by10), W/m^2. 2 – Temperature of the rhizome or the top surface of hoarfrost, °C. 3 – Thickness of hoarfrost layer (multiplied by 10), mm. 4 – Density of the heat flux escaping from the surface of the rhizome or hoarfrost (divided by10), W/m^2

CONCLUSIONS

Presented model shows that the temperature of the rhizome surface does not fall below the freezing point immediately after the sunset. Therefore, the sprinkler systems that protect the plants can be activated at a later point in time upon receipt of signal from the measuring device about rapid cooling and decreasing temperature. At first one has to sprinkle a little to create conditions for occurrence of hoarfrost. The results demonstrate that hoarfrost protects the plants against temperature decrease. This means one has to ensure that the relative humidity of air is as high as possible so hoarfrost can occur already at the temperature of –0.5 °C. It is not advisable to sprinkle too much since this causes formation of ice instead of hoarfrost; an ice layer does not protect the plant against the cold without water sprinkling.

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40. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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Prethodno priopćenje
Preliminary communication

APPLES IMPACT ON A RIGID PLANE SURFACE: PREDICTION AND EXPERIMENTAL DATA COMPARISON

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SUMMARY

Among the mechanical actions faced on the fruits, in post harvest operations the most frequent are the impacts, which may cause them damages.

Simulating the impact response of fruits has an important role in prediction of the characteristics of impact as required in the estimation both of their mechanical injuries and their correlation with fruit ripeness degree.

In this paper we develop a mathematical model of response to the impact of fruits in the form of differential equations based on the assimilation assumption of fruits, with rheological Kelvin – Voight linear viscoelastic bodies.

The numerical integration of the differential equation of simulation it was made, applying the Runge – Kutta method, using a program developed in Turbo – Pascal by the authors. For integration were considered the mechanical characteristics for 3 local apples varieties determined by our own experiments. Were determined the force – time and force – deformation curves during the impact. These curves which simulated the real curves, obtained from experiments and known both in the scientific literature, being similar to them, and witch are obtained in our experiments for 3 varieties of apples: Jonathan, Golden Delicious and Idared. It was tested and comparing the estimated values by simulating and measured at experiments for the most important impact characteristics - the peak force, ascertaining the insignificant differences between them. Knowledge of these curves allows to obtain the Fmax at impact, which are necessary to evaluation the rank of injury of apples and/or the functional and structure parameters of various mechanical systems, from the post harvest operations chain.

Also, these characteristics can be correlated with the degree of ripeness of the fruits, proper used in some sorting systems implementation.

Key words*: impact, viscoelastic, apples, mathematical model, impact characteristics*

INTRODUCTION

During the post harvesting operational chain, from sorting – packaging, to transportation and manipulation, in order to prepare the fruits for the market and/or storage of the fresh fruits, the apples suffer under varied mechanical forces, the most frequent one being the impact For agriculture products the impact is defined for contact velocity higher than 25 cm/s, [1,3], while for the activity process of mechanical systems the contact velocity is usually higher than 30 cm/s. As a stress effect, the fruits get damaged. The highest fruits losses during storing period, aprox. 10 – 12 % are due to mechanical damages during sorting – packaging, manipulation, transportation, handling etc., [1,2]. Damages are highlighted by concussions followed by the pulp's change of color in brown or cracks, [1,3,13], and they are caused when the tensions are higher than the elastic limit of the fruit's pulp.

The damage degree depends on the variety of the fruits and the ripeness degree, on the geometrical shape and the development factors registered in the orchard, on the complexity and the constructional and functional parameters of the technical system, on the type and the work regime, on the time passed between harvesting and processing, [18].

The evaluation of different fruits varieties reaction to impact, especially apples, has reached a worldwide interest, [6,9,10,12,15,17,18,19].

Simulations and experiments related to the behavior of the fruits during impact has special attention, research related, [5,7,8], in order to correlate the damage level to the causing impact force level and to create mathematical models able to predict the damaged caused by impact.

In recent studies the issue of the damage of the fruits during impact involves elements more and more complex as probable characteristics of the damage correlated to different natural and circumstantial factors describing the process, [18].

The concept of parameter of susceptibility to damage during impact has been developed while it is considered that the damage level will not be higher than a certain permitted value (in reality 10%, [18]), while considering the natural variability of the influence factors, this index is defined by kinetic energy.

Also experimental research based on the fruit's reaction to impact in order to appropriately correlate it with the solidity (consistence) of the structure (tissues) directly linked to the ripeness degree, were used in the fruits sorting process, [4,5,10]. In this matter the applications [4,10] point out that the indicator which best sorts out the different degrees of ripeness correlated with the texture changes, is defined by $C = F_{\max}/t_c$ where $F_{\max}$ is the maximum force of impact, t_c– the time between the beginning of the impact until the $F_{\max}$ (time to peak) is reached.

The goals of this study have been a) developing a mathematical model for the simulation of the impact between apples, considered bodies with a linear viscoelastic flow, on plane fixed and rigid surfaces, in order to evaluate the maximum of the forces involved in impact (the main characteristic of the impact causing the damages) and marking the force – time curve during impact; b) experimenting the impact at 4 initial velocities for 3 varieties of local apples: Jonathan, Golden Delicious and Idared, in order to calculate the maximum value of the impact force; c) testing and comparing, through experiments, the estimated values and the measured values for the main impact parameter (maximum force). Knowing these curves, the characteristics of the impact can be obtained and used to evaluate the level of the damage upon apples and/or the functional and constructional parameters of different mechanical systems used in the transportation-selection-packaging operational chain used to process the fruits.

In many research studies, apples have been considered homogeneous and isotropic materials, [4], and recent research take into account the inhomogeneous and anisotropic characteristics in the apple's parenchymatous tissue, [7,8] in order to obtain more exact information.

THEORETICAL ELEMENTS

In relatively recent studies the impact of the fruits is approached considering their unidimensional viscoelastic behavior, using either the Maxwell model [6], or, the Kelvin-Voight model where the simulation of the impact is closer to the real situations, [11, 13]. A more complex physical model of the impact has been developed by the authors [20], upon the analysis of the force- strain curve for a viscoelastic material compressed with a constant velocity, derived from the Kelvin-Voight model, fig.1.

Following this curve, the OA segment represents the elastic behavior, AB is the segment where, along with the elastic behavior we can observe the viscous damping due to the viscous component having as result a viscoelastic behavior.

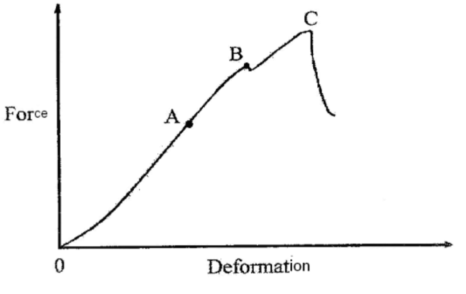

Fig. 1 The curve force - ideal strain for a viscoelastic material solicited to compression and constant velocity, [15]

On the AB segment of the curve force – strain can be observed multiplying damage upon cells spreading through the material, phenomenon assimilated to the plastic behavior observed at strains bigger than the ones corresponding to the point B bioyield point on the curve.

Based on this concept and a suggestion in [16] we can create the equivalent chart (Kelvin – Voight model) for the impact of viscoelastic bodies with rigid plane surface by introducing a plastic strain element. This chart can be seen in fig. 2 where: F_a – elastic segment of contact force; F_d – the absorbing viscous segment and F_p – dissipative segment given by the plastic strain.

Thereby the relation for the total force F(t) during impact, in general form, will be:

$$F(t) = F_a(\delta) + F_d(\delta, \dot{\delta}) + F_p(\delta, \dot{\delta}) \tag{1}$$

where δ, $\dot{\delta}$ are the strain and the velocity of the body during impact.

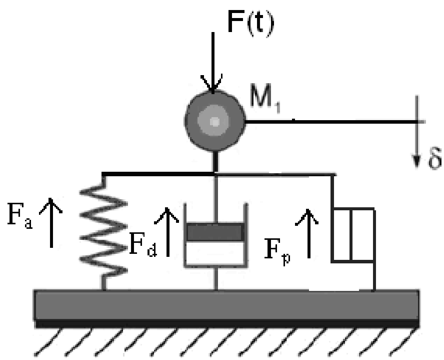

Fig. 2 Model for the pair impact – Kelvin equivalent model completed by the element with plastic behavior (F_p)

The contact force segment due to plasticity is present only at big strains followed by cells ruptures spreading through the product so that we can determine a critical value of this force F_{pc} creating cells rupture, so:

$$F_p(\delta, \dot{\delta}) = \begin{cases} 0, F_p < F_{pc} \\ F_p, F_p \geq F_{pc} \end{cases} \tag{2}$$

When the strains are minor, no ruptures are registered

$$F_p(\delta, \dot{\delta}) = 0$$

equation (1) becomes:

$$F(t) = F_a(\delta) + F_d(\delta, \dot{\delta}) \tag{3}$$

Terms in eq. (3) can be expressed by the relations, [4, 5]:

$$F_a(\delta) = K\delta^{3/2} \tag{4}$$

$$F_d(\delta,\dot{\delta}) = \beta\delta^{3/2}\dot{\delta} \tag{5}$$

where K – contact rigidity for impact.

In equation (5) the coefficient β is dumping hysteresis factor which can be expressed in a new way in the equations [4, 5]:

$$\beta = \frac{3}{4}K\frac{1-k^2}{V_i} \tag{6}$$

where: k is the impact's restitution coefficient, given by the equation

$$k = 1-\alpha V_i \tag{7}$$

V_i – the velocity at the beginning of the impact.

With the relations (4), (5), (6) replaced in (3) and the equation of the movement during impact, ($M_1\ddot{\delta}+F(t)=0$) we get:

$$\ddot{\delta}+\frac{K}{M_1}\delta^{\frac{3}{2}}+\frac{3}{4}\frac{K}{M_1}\frac{1-k^2}{v_i}\delta^{\frac{3}{2}}\dot{\delta}=0 \tag{8}$$

$$F(t) = K\delta^{\frac{3}{2}}+\frac{3}{4}K\frac{1-k^2}{v_i}\delta^{\frac{3}{2}}\dot{\delta} \tag{9}$$

where M_1 is the mass of the apple.

If in the equation (6) we replace the restitution coefficient for impact k in equation (7), after calculating we get:

$$\beta = \frac{3}{4}K\alpha\left(2-\alpha^2V_i\right) \tag{10}$$

Usually $V_i < 1$ m/s and considering that α < 1, results that $\alpha^2 V_i << 1$, which permits, at the first approximation, the lapse of the value of $\alpha^2 V_i$ în eq.(10), and we get:

$$\beta \cong \frac{3}{2} K\alpha = \frac{3}{2} k_c \alpha \tag{11}$$

where k_c - contact rigidity of apple at impact with a rigid plane surface

Based on elastic contact Hertz theory, result, [3,9]:

$$k_c = 0{,}943 \cdot \frac{E}{1-\nu^2} \cdot d^{1/2}, \tag{12}$$

where E – elasticity modulus, υ – Poisson coefficient, d – apple diameter

This way the movement equation (8) and the impact force equation (9) during impact become:

$$\ddot{\delta} + \frac{3}{2} \frac{\alpha k_c}{M_1} \delta^{3/2} \dot{\delta} + \frac{k_c}{M_1} \delta^{3/2} = 0 \tag{13}$$

$$F(t) = k_c \delta^{\frac{3}{2}} + \frac{3}{2} \alpha k_c \delta^{\frac{3}{2}} \dot{\delta} \tag{14}$$

This is how the Hunt and Crosley equations have been calculated, [13]. In our research, [19,20] we demonstrated by integrating the two types of equations (8), (9), respectively (13), (14) using data collected during our own experiments on apples and obtaining insignificantly different results.

There for in our numerical simulation we will use the form of eq. like (13), (14).

Integrating equation (13), results the variance of the strain during impact dependent of time, and using the equation (14), results the variation of the impact force dependent of time $F(t)$ and the variation of the force depending on the strain, $F(\delta)$, representing the curves force - time or force – strain during impact. Using these curves we can appreciate the characteristics of the impact and we will use in this paper only F_{max},

The differential equation was integrated using the Runge-Kutta method using a Turbo-Pascal [14] application conceived by the authors, with the data obtained were graphically displayed the force variation F, during impact depeding, on time.

The model can be adjusted to simulate the behavior (reaction) to impact for apples as viscoelastic materials, and the simulation results obtained were compared with the results found by us, in the experiments.

This is the model created by Hunt and Crossley and it can be used to simulate the energy loss during impact between a rigid body and an elastic hemispace (the apple). For this reason the model can be adjusted to simulate the behavior during impact for apples, considering the fruits as viscoleastic materials, and at low impact velocity the contact surface behaves as an elastic hemispace.

Due to the natural variation of the parameters E, α, k_c, V_i, M_1 that change the values of the coefficients in the mathematical models for the fruits impact (linear viscoelastic bodies) expressed in the equations (13) and (14) for simulating the impact all circumstances from our experiments were considered

MATERIALS AND METHODS

During experiments we used 3 varieties of local apples, fresh: Jonathan, Idared and Golden Delicious.

We created groups of 9 apples for each of the 4 impact velocities and respectively for each variety of apples, using 36 apples for each variety. The fruits have been weighted, measured geometric dimensions (minimum and maximum diameter, height and radius of curvature of the surface at the impact point) and then subjected to impact using the pendulum method at the initial velocities 1,04 m/s; 0,83 m/s; 0,67 m/s; respectively 0,5 m/s. The pendulum was provided with a carbon fiber rod length 610 mm, and with an accelerometer fixed on apple through an elastic connection, a signal conditioner and a data acquisition board were integrated and connected to a computer, and with the possibility of measuring the angle of the rod at launching and returning on a sector graduated from an indicator jointly with the rotation axis of pendulum.

Acceleration-time curves at the impact, and the returning angle of rod after impact, necessary to calculate the velocity at the end of impact and for restitution coefficient, have been created for every single fruit.

The experimental study of the impact of the apples with the pendulum has been realized using a Labview application which has a user interface that allows the configuration and calibration of the system, the data acquisition and primary data analysis and the visualization of the impact. During an initial phase the maximum force during impact has been determined by experiments and simulations, one of the most important parameters of the impact with the main role in damaging the apples. The data collected during the two situations has been compared in order to be used to simulate the prediction of the maximum impact force.

RESULTS AND COMMENTS

For values of the geometrical and mechanical characteristics from the domain of our experiments, for the Golden apples variety: $V_i = 0{,}5\ldots1{,}04$ m/s; $E = 1{,}1\cdot10^6\ldots4{,}5\cdot10^6$ Pa; $\alpha = 0{,}567\ldots0{,}8$ s/m, [1,3], determined the domains of variation of the coefficient $k_c = 0{,}3\cdot10^6\ldots1{,}33\cdot10^6$ N/m$^{3/2}$ and $3/2\alpha k_c = 0{,}35\cdot10^6\ldots1{,}42\cdot10^6$ N/m$^{3/2}$. in all these cases have been used apples with masses between $m = 87{,}4\ldots159{,}32$g, diameters between 56 and

91 mm and the Poisson's coefficient υ = 0,37, [3]. The maximum force for all 3 apples varieties has been determined experimentally and by simulation to be presented shortly.

Therefore, for the G6 case we will present the calculation mode, introducing the values of this case in equations (13) and (14), and will result:

$$\ddot{\delta} + 6 \cdot 10^6 \delta^{\frac{3}{2}} \dot{\delta} + 7{,}057 \cdot 10^6 \delta^{\frac{3}{2}} = 0 \tag{15}$$

$$F(t) = 0{,}803 \cdot 10^6 \delta^{\frac{3}{2}} + 0{,}825 \cdot 10^6 \delta^{\frac{3}{2}} \dot{\delta} \tag{16}$$

Integrating the differential equation (15) for the initial conditions t = 0, $\delta(0)$ = 0, and $\dot{\delta}(0) = V_i = 0{,}83 m/s$, for a interval $\Delta t = 10^{-4} s$, using the Runge – Kutta method and a computer program created in Turbo-Pascal by the authors, [14], we were obtained the force variation during impact, graphically displayed in fig. 3, and it can be read the estimated value of $F_{max} \approx 54$ N.

Following the same methodology, other cases have been studied for other values, from their real variation domain, of the mechanical and geometrical characteristics for 3 apples varieties, specified in table 1.

Therefore, the estimated values of F_{max} for all 108 cases from the experiment were obtained by the simulation model. Some of these values are selected and presented in tab 1.

For the experimental part, using a aplication in Labview, after we obtained the datas regarding the apples acceleration during impact (according to the relation $F=ma$, m – mass of apple, a – acceleration), the force variation was registered and graphically displayed in fig. 4 for the same case, G6. From fig. 4 we can read the estimated F_{max}=49,5 N.

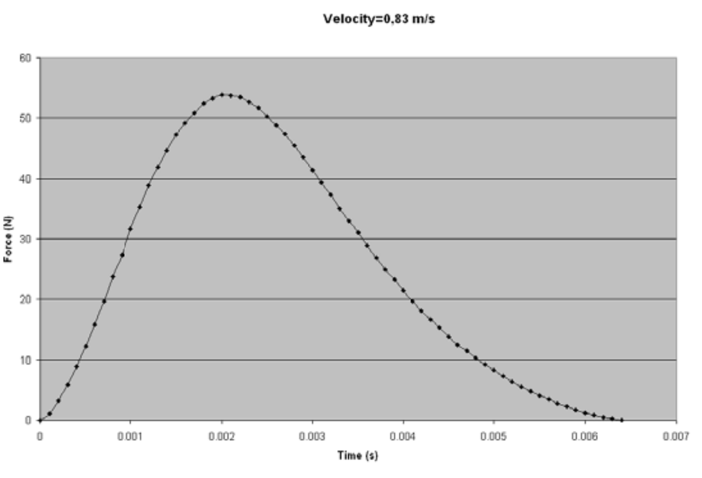

Fig. 3 Force variation during impact, depending on time, obtained from simulation

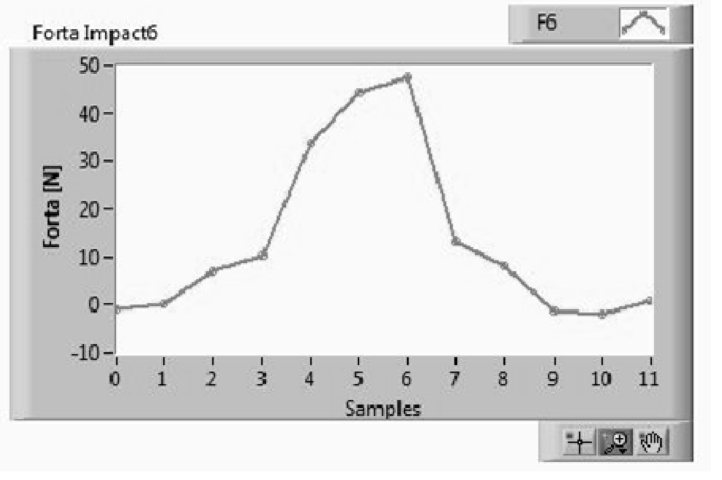

Fig. 4 Force variation during impact, depending on time, obtained from experiments

These values presented in tab. 1 are the most significant values of peak force, for all 3 varieties of apples used in experiments. In tab. 1 were noted by G – the Golden Delicious variety; J – Jonathan variety, I – Idared variety, and the relative error for F_{max},

$$\varepsilon\ (\%)=100\cdot(F_{max\ c}-F_{max\ m})/\ F_{max\ m}.$$

Tab. 1 The comparative values of measured and estimated F_{max} for some cases for 3 apples varieties

Nr. crt	Nr. cod	v_i (m/s)	F_{max}(N) measured	F_{max}(N) calculate	ε (%)
1	G1	1,04	81,61	78,41	-4,1
2	J15	1,04	102,52	103,18	0,6
3	I14	1,04	106,46	110,65	3,8
4	G6	0,833	49,45	53,88	8,2
5	J18	0,833	69,90	70,58	1,0
6	I18	0,833	88,90	89,66	0,8
7	G8	0,667	21,82	23,70	7,9
8	J21	0,667	57,67	57,83	0,3
9	I20	0,667	70,76	70,63	-0,2
10	G11	0,5	24,77	25,36	2,3
11	J23	0,5	43,01	42,02	-2,4
12	I22	0,5	51,25	52,87	3,1

Examining the values in tab. 1 we will observed that in over 70% of cases the errors for the F_{max} estimated values, compared to F_{max} measured values is between -4,1% and +8,2%, and the other cases had the errors just over ± 10%.

Has also been established that for all the 108 cases considered, the variation curves of the followed parameters (F(t)) were similar with the ones presented in fig. 3, for simulation, and like in fig. 4, for the experimental values. This fact proves that the differential equations (13) and (14) describe with sufficient accuracy the F force variation, during impact, depending on time and the values of F_{max} approximate sufficiently the real values.

These data about Fmax during impact are useful in predicting the Fmax value, required in design engineering activities and using specific equipment for the mechanical sorting of the fruits.

CONCLUSIONS

Starting from theoretical studies upon the impact between viscoelastic bodies on rigid plane surfaces (using the Kelvin – Voight model), applied on apples, a differential mathematical model has been elaborated which simulates the real behavior during impact. The solutions for these equations describe the force – time curves during impact which permit the obtained of F_{max}, that characterize the impact and are necessary to evaluate the degree of damage suffered by the apples and/ or the functional and constructive parameters of different mechanical systems included in the operations chain: transportation, sorting, packaging.

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