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MOGUĆNOST PRIMENE VIRTUALNOG ROTIRAJUĆEG ČEŠLJA KOD MEHANIZOVANOG UBIRANJA CVASTI NEVENA (*Calendula officinalis* L.)

Branislav Veselinov[*1], Dušan Adamović[2], Marko Golub[1], Miodrag Višković[1], Milan Martinov[1]

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Sažetak: Cilj istraživanja bio je da se ispita mogućnost mehanizovanog branja cvasti primenom radnog organa tipa virtualnog rotirajućeg češlja, koji se koristi za ubiranje kamilice.

Ispitan je uticaj koeficijenta *R*, koji predstavlja odnos dubine ulaska radnog organa u horizont cvasti i prosečne visine raspona najviših i najnižih cvasti na biljkama, na efikasnost ubiranja.

Ustanovljeno je da pri veličini koeficijenta *R* = 1,3 može da se ostvari maksimalan udeo ukupne ubrane mase cvasti u biološkom prinosu cvasti u proseku 90 % (cvasti sa drškom dužine do 2 cm 65 % i preko 2 cm 35 %, obračunato na dužinu do 2 cm).
Buduća istraživanja treba da se usmere ka rešavanju mehaničkog postupka separacije cvasti od stabljike i lišća i skraćivanja drški cvasti, kao i utvrđivanja ekonomske opravdanosti mehaničke berbe cvasti nevena prikazanim postupkom.

Ključne reči: *neven* (*Calendula officinalis* L.), *cvast, ubiranje, mehanizacija, radni organ.*

[*] Kontakt autor. E-mail: branislavveselinov@uns.ac.rs

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UVOD

Neven *(Calendula officinalis* L.*)* se direktno seje na razmaku 40–60 cm, od početka aprila, a može i kao postrni usev u julu [1]. Gaji se u plodoredu, a cvasti se uglavnom beru ručno. Posle branja cvasti treba brzo osušiti kako bi se sprečio gubitak njihovog kvaliteta. Prinos suve cvasti je 500–800 kg ha^{-1}, međutim, u zavisnosti od broja i termina branja znatno varira, pa može biti i veći [2], [3].

Ručno branje cvasti obavlja se obično svakih 3 do 5 dana, sa prosečnim učinkom oko 4 kg h^{-1}, što predstavlja intenzivno, pa samim tim i skupo radno opterećenje u procesu proizvodnje nevena, ali obezbeđuje kvalitetan ubrani materijal i nije potrebna naknadna dorada u pogledu separacije cvasti od primesa.

Za velike površine, preko 3 ha, ne isplati se upotreba ljudske radne snage za branje, pa se u takvim slučajevima mora primeniti mehanizovan način branja cvasti

Mogućnosti mehanizovane žetve cvasti kamilice, nevena i kantariona pomoću mašina za branje cvasti, koje imaju radni organ izveden kao rotor sa češljevima malog razmaka između zuba, prikazane su u radovima [4], [5] i [6]. Međutim, u [5] i [7] navodi se mogućnost mehanizovanog branja cvasti kamilice i buhača pomoću mašine, koja ima radni organ u obliku virtualnog rotirajućeg češlja sa zubima širokog razmaka i koja je značajno jevtinija od raznih rešenja sa rotirajućim češljevima malog razmaka zuba. S obzirom da neven ima sličnu građu kao i kamilica, pretpostavljeno je da i cvast nevena može da se ubira mašinom sa istim tipom radnog organa.

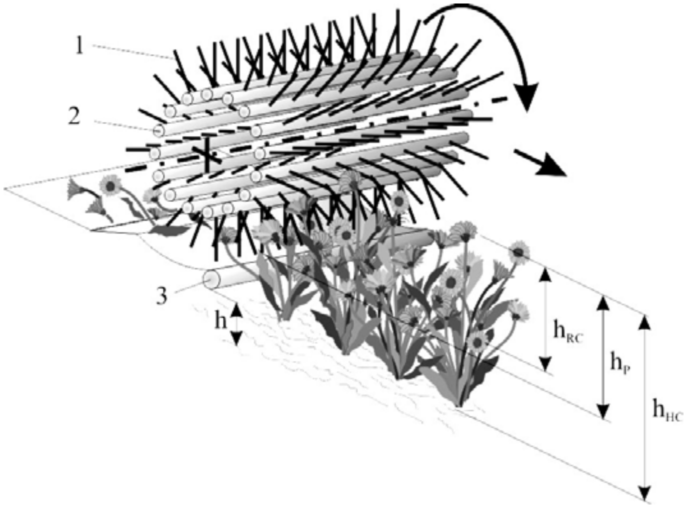
Slika 1. Traktorom nošena mašina za branje cvasti kamilice sa radnim organom tipa virtuelnog rotirajućeg češlja sa zubima širokog razmaka
Figure 1. Tractor mounted harvester used for mechanical harvest of chamomile inflorescences with virtual rotating comb

Pri mehanizovanom branju cvasti nevena, međutim, dolazi do smanjenja broja pupoljaka, jer radni organ berača ne razlikuje pupoljak od cvasti, što u određenoj meri utiče na smanjenje prinosa cvasti, a potrebna je i naknadna dorada kako bi se odvojila stabljika i lišće i dužina drški cvasti svela na dužinu do 2 cm. Zbog toga je postavljen cilj da se istraži mogućnost mehanizovanog branja cvasti nevena primenom mašine namenjene za branje cvasti kamilice, koja ima radni organ tipa virtualnog rotirajućeg češlja sa prstima širokog razmaka (Sl. 1), utvrđivanjem radnih parametara pri kojima se ostvaruju najbolji efekti branja.

MATERIJAL I METOD

Dvogodišnje istraživanje efikasnosti branja cvasti nevena sorte „Gelb Orange“ pomoću mašine sa radnim organom tipa virtuelnog rotirajućeg češlja sa zubima širokog razmaka obavljeno je na Institutu za ratarstvo i povrtarstvo, Odeljenju za hmelj, sirak i lekovito bilje, kod Novog Sada. Neven je gajen na parceli površine 0,12 ha. Međuredni razmak bio je 45 cm, a gustina sklopa 300,000 biljaka po hektaru. Primenjena je standardna agrotehnika. Parcela je podeljena na šest delova sa jednakim brojem redova biljaka.

Mašina za branje [8] imala je radni organ radne širine 1.200 mm i prečnika putanje vrhova zuba 720 mm, Sl. 2. Zubi – 1, prečnika 5 mm bili su raspoređeni na 16 cevastih nosača – 2, na međusobnom razmaku 50 mm. Dužina svakog prsta iznosila je 75 mm. Podužni raspored zuba na svakom susednom nosaču je smaknut, tako da se pri obrtanju formira zavojnica. Prevojna cev – 3 bila je postavljena na udaljenosti 10 mm od vrhova zuba. Iza radnog organa nalazio se prijemni sanduk za ubranu masu zapremine oko 1 m^3.



Slika 2. Radni organ za branje cvasti tipa virtualnog rotirajućeg češlja sa zubima širokog razmaka 1 – prsti, 2 – cevasti nosači prstiju, 3 – prevojna cev, *h* – visina prevojne cevi od tla, h_{RC} – raspon najviše i najniže cvasti na biljci, h_P – dubina ulaska virtuelnog rotirajućeg češlja u cvetni horizont, h_{HC} – visina horizonta cvasti

Figure 2. Virtual rotating comb type harvester, with wide tines' distance 1 – tine, 2 – tines' carrier, 3 – round tube, h – tube's height, h_{RC} – width of inflorescences band, h_P – depth of working device penetration into the inflorescences horizon, h_{HC} –inflorescences horizon height

Ispitivanje efikasnosti branja obuhvatilo je utvrđivanje vrednosti prosečnog udela ukupne ubrane mase cvasti M_C (cvasti dužine drške do 2 cm i preko 2 cm, obračunato na dužinu drške do 2 cm) u biološkom prinosu cvasti M_{BC}, za različite vrednosti odnosa dubine ulaska radnog organa u horizont cvasti h_P i prosečne visine raspona najviših i najnižih cvasti na biljkama h_{RC}, izraženog pokazateljem (1):

$$R = \frac{h_p}{h_{RC}} \tag{1}$$

gde je:
R [-] - koeficijent,
h_p [cm] - dubina ulaska radnog organa u horizont cvasti,
h_{RC} [cm] - prosečna visina raspona najviših i najnižih cvasti na biljkama.

Branja su obavljana svakih 15 do 20 dana, nakon formiranja cvasti, pri frekvenciji obrtanja radnog organa 130 min^{-1}, sa prosečnom radnom brzinom kretanja mašine 1,1 $km \cdot h^{-1}$ (Sl. 3).

Slika 3. Mašina sa virtualnim rotirajućim češljem pri branju cvasti nevena
Figure 3. Tractor with virtual rotating comb type harvester in marigold inflorescences harvest

U toku obe sezone obavljeno je po 5 branja. Na svakom delu parcele, u toku prve sezone primenjena je drugačija vrednost R, koja je bila u intervalu 1,0–2,4, sa intervalom povećanja 0,1. Kako je, na osnovu rezultata ispitivanja u prethodnoj godini, uočeno da su najbolji efekti branja ostvareni za vrednost R = 1,3, druge sezone je primenjena samo ta vrednost. Vrednost R podešavana je na početku svakog dela parcele, podešavanjem visine h prevojne cevi – 3 (Sl. 2), od tla, u skladu sa izrazom (2):

$$h = h_{HC} - (R \cdot h_{RC} + 4{,}5) \tag{2}$$

gde je:
h [cm] - visina prevojne cevi od tla,

h_{HC} [cm] - visina horizonta cvasti,
4,5 [cm] - zbir prečnika prevojne cevi (3) i udaljenosti vrhova zuba od prevojne cevi (Sl. 2).

Posle svakog prohoda merena je količina ukupne ubrane mase biljke nevena i izračunata vrednost u kg·ha^{-1}. Iz ubrane mase, na slučajan način, izdvojeno je po 5 uzoraka mase oko 1 kg iz kojih su cvasti ručno separisane od stabljike i lišća. Cvasti su klasifikovane u dve grupe, na osnovu dužine drške, do 2 cm (prva klasa) i preko 2 cm i izmerene njihove mase $M_{C\leq 2}$ i $M_{C>2}$, redom. Izračunate su prosečne vrednosti, koje su obračunate u kg·ha^{-1}.

Nakon toga obavljeno je ručno skraćivanje drške cvasti druge grupe na dužinu do 2 cm, te izmerene mase cvasti. Odnos mase odsečenih drški i ukupne ubrane mase $M_{C>2}$ predstavlja koeficijent ε. Ukupna ubrana masa cvasti M_C izračunata je pomoću izraza (3):

$$M_C = M_{C\leq 2} + M_{C>2} \cdot (1 - \varepsilon) \tag{3}$$

gde je:
M_C [kg·ha^{-1}] - ukupna ubrana masa cvasti nevena,
$M_{C\leq 2}$ [kg·ha^{-1}] - masa cvasti dužine drške do 2 cm,
$M_{C>2}$ [kg·ha^{-1}] - masa cvasti dužine drške preko 2 cm,
ε [-] - koeficijent.

Posle mehanizovanog branja ručno sa 1 m^2, na slučajan način, sa pet ponavljanja, sakupljene su cvasti, koje su ubrane ali su pale na zemlju, kao i one, koje tokom procesa branja nisu otkinute. Time su ustanovljeni prosečni ukupni gubici cvasti pri branju, M_G, obračunati u kg·ha^{-1}, svedeni na dužinu drške do 2 cm primenom koeficijenta ε.

Biološki prinos cvasti M_{BC} utvrđen je sabiranjem ubrane mase cvasti M_C i ukupnih gubitaka cvasti pri branju M_G, za svako branje.

Ispitivanje efikasnosti ubiranja, za različite vrednosti pokazatelja R, definisano je sledećim pokazateljima:

- udeo ubrane mase cvasti M_C u biološkom prinosu cvasti M_{BC}, (4):

$$k1 = \frac{M_C}{M_{BC}} \cdot 100 \tag{4}$$

gde je:
k1 [%] - udeo ubrane mase cvasti u biološkom prinosu cvasti,
M_{BC} [kg·ha^{-1}] - biološki prinos cvasti.

- odnos ubrane mase cvasti dužine drške do 2 cm ($M_{C\leq 2}$) i mase cvasti dužine drške preko 2 cm ($M_{C>2}$) obračunato na dužinu drške do 2 cm (5):

$$k2 = \frac{M_{C\leq 2}}{M_{C>2}} \tag{5}$$

gde je:
k2 [-] - odnos ubrane mase cvasti dužine drške do 2 cm i mase cvasti dužine drške preko 2 cm.

REZULTATI I DISKUSIJA

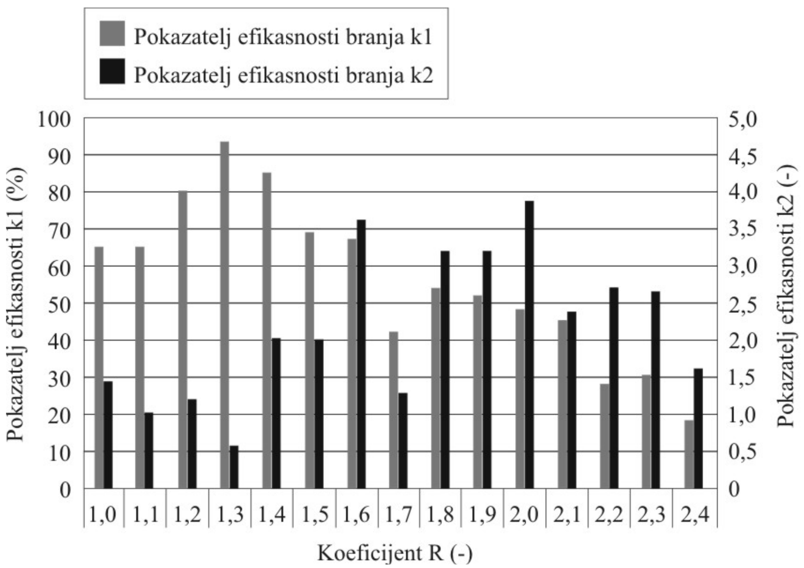
Tokom obe godine istraživanja, vrednosti prosečne visine horizonta cvasti i raspona najviših i najnižih cvasti imali su približno konstantan pad (prve godine: 52 - 39 cm i 18 - 8 cm redom, a druge godine: 46 - 28 cm i 15 - 8 cm redom). Takođe je vrednost udela cvasti u masi biljke imala trend opadanja (prve godine: 18 - 14,5 cm, a druge godine: 15 - 12,7 cm, redom).

Prosečan prinos cvasti tokom prve godine branja imao je stohastičan karakter. Značajno najveći prosečan biološki prinos cvasti bio je pri prvom branju, 4.157 $kg{\cdot}ha^{-1}$, a potom se smanjivao u narednim branjima, tako da je kod petog branja iznosio oko 24 % prinosa pri prvom branju (994 $kg{\cdot}ha^{-1}$).

Druge godine, prosečan prinos cvasti kretao se u granicama 1.200 - 1.750 $kg{\cdot}ha^{-1}$, bez tendencije smanjenja u odnosu na prvo branje.

Udeo mase odsečenih drški cvasti, koje su duže od 2 cm, u ukupnoj masi ubranih cvasti, koje imaju drške dužine preko 2 cm, tokom dve godine branja, u proseku je iznosio 33,6 %.

Najveći udeo prosečne ukupne ubrane mase cvasti M_C u prosečnom prinosu cvasti M_{BC}, prve godine branja, iznosio je $k1 = 93$ % i ostvaren sa vrednošću $R = 1{,}3$, a najmanji, $k1 = 18$ %, sa $R = 2{,}4$. Najveća vrednost odnosa prosečne mase ubranih cvasti dužine drške do 2 cm, $M_{C\leq 2}$, i preko 2 cm, obračunato na dužinu drške do 2 cm, $M_{C>2}$, iznosila je $k2 = 3{,}9$ i ostvarena je pri $R = 2{,}0$, a najmanja, $k2 = 0{,}6$, pri $R = 1{,}3$ (Sl. 4).



Slika 4. Pokazatelji *k1* i *k2* za različite vrednosti koeficijenta *R*, prve godine ispitivanja branja
Figure 4. Indicators k1 and k2 for different values of coefficient R, first season of testing

Pri vrednosti $R = 2{,}3$ i 2,4 značajno su izraženi ukupni gubici cvasti, u odnosu na biološki prinos cvasti, 70 i 82 % redom. Pri tome se gubici u najvećem procentu odnose na neubrane cvasti, čak 97 %, odnosno 98 %, redom, dok je bilo svega 2 - 3 % cvasti koje su pri branju pale na zemlju, redom. Značajno manji gubici ostvareni su pri vrednosti *R* = 1,3, u proseku 3 %, od čega je gubitak u cvastima, koje su pale na zemlju, iznosio 45 %, a neubranih cvasti 54 %.

Druge godine su potvrđeni rezultati ocena efikasnosti branja cvasti dobijeni u prvoj godini, s obzirom na podešenost visine rada radnog organa *R* = 1,3. Može se konstatovati da ovakav rezultat utvrđivanja ocene efikasnosti branja ukazuje na činjenicu da dubina ulaska prstiju virtualnog rotirajućeg češlja u horizont cvasti treba da bude 30–40 % veća od prosečnog raspona najviših i najnižih cvasti. Na taj način može da se postigne da odnos količine ubranih cvasti i prinosa cvasti bude najveći. Takođe, u ubranoj masi biljke može da se ostvari odnos cvasti sa drškom dužine do 2 cm i preko 2 cm približno 2:1.

Potrebno je da se reše postupci za separaciju ubrane zelene mase i skraćivanje drški ubranih cvasti, koje imaju dužinu preko 2 cm, na dužinu do 2 cm. Jedno od rešenja načina skraćivanja drški moglo bi da bude primena uređaja, koji se za istu namenu primenjuje u doradi cvasti kamilice [9].

ZAKLJUČAK

Na osnovu dvogodišnjeg istraživanja mogućnosti mehanizovanog branja cvasti nevena može da se zaključi:

- Mašina, sa radnim organom tipa virtualnog rotirajućeg češlja, sa zubima širokog razmaka, mogla bi efikasno da bere cvasti nevena. Pri tome može da se ostvari najveći udeo ukupne ubrane mase cvasti u prinosu cvasti 84–93 % (računato sa dužinom drške do 2 cm), pri 30 do 40 % većoj dubini zadiranja radnog organa u horizont cvasti od prosečnog raspona najviših i najnižih cvasti.
- Kao posledica oštećenja pupoljaka, naredno branje ostvaruje se nakon 15 do 20 dana, u zavisnosti od meteoroloških uslova.
- Potrebno je da se reši separacija ubranih cvasti od stabljike i lišća, kao i postupak skraćivanja drški cvasti, koje su duže od 2 cm na dužinu do 2 cm.

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POSSIBILE APPLICATION OF VIRTUAL ROTATING COMB IN MECHANIZED HARVESTING OF MARIGOLD INFLORESCENCES *(Calendula officinalis* L.*)*

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Abstract: The objective of the investigation was to examine possibility of mechanized harvesting of marigold inflorescences by applying a virtual rotating comb type chamomile harvester.

The impact of coefficient R, relation between the working device penetration into the inflorescences horizon and the average value of highest and lowest inflorescences span-width of inflorescences band, on harvest yield, was tested. It was found that for coefficient R value 1.3, in average 90 % of the inflorescences' yield can be harvested.

Future investigation should be directed towards solving the mechanical separation of the inflorescences from the harvested mass and process of shortening the inflorescences' stems and determination of economic viability of mechanized harvest with proposed procedure.

Key words: *marigold* (*Calendula officinalis* L.), i*nflorescence, mechanized, harvest, rotating comb.*

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FEM ANALYSIS OF PROTECTIVE FRAME ON ORCHARD TRACTORS IN ROLLOVER CASE

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Abstract: This paper describes a design of the protective frame orchard tractors and tractor power up to 65kW for use in fruit production on sloping ground for mechanical harvesting (shaking) of stone fruits. Shown protective frame can be mounted on existing models of tractors, primarily domestic production. This paper presents an analysis of the stress state of the observed protective frame mode unwanted case overturning tractor. A common practice in the examination and approval of protective frames to be loaded twice the force of gravity of the tractor. Analysis of the protective frame was done using the software package SolidWorks gain and methods of FEM analysis. Ram is loaded with a horizontal and vertical force of 38,2 kN on the side and from above. The results obtained show a satisfactory security.

Key words: *tractor, protective frame, rollover, FEM analysis, load.*

INTRODUCTION

Agricultural tractors are required to have roll-over protective structures (ROPS) for use on European roads. To that end, the ROPS must conform to a series of strength tests in accordance with the Organization for Economic and Co-operation Development (OECD) Standard Codes or the relevant European Community (EC) Directives. Within these Codes, ROPS force and energy absorption test requirements are typically defined in terms of a 'reference mass'. This mass, along with mass values for 'unladen',

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'ballast', and 'maximum laden', required for the homologation documentation, is given by the tractor manufacturer. Recent international interest in operator safety has questioned the appropriateness of the mass definitions and specifically the use of the currently defined reference mass as the basis for ROPS testing.

Tractor roll-overs continue to be one of the most common causes of death and injuries on farms. Tractor operators are most at risk of injury when [1-8]:

- their tractor does not have ROPS,
- the operator does not wear fitted seatbelts,
- equipment is poorly maintained,
- working on sloping terrain,
- working on rough, slick or muddy surfaces,
- towing or pulling objects or loads,
- travelling through pastures where high vegetation can obscure stumps and/or pot holes,
- working near dams, ditches, irrigation channels, embankments or over hanging structures.

So far, risk monitoring indicate the occurrence of different hazards when working with certain types of machines. In order to take preventive measures, it is important to have complete information about the machine and operating conditions. Since tractors working on uneven terrain (fields with canals for irrigation, etc.), the occurrence of rollover accidents are very common.

In accordance with standards and EU directives for machinery, defines three main objectives to protect machine operators in the event of a rollover of the same [9]:

- maintain the required floor space,
- able to prevent the operator runs out of space and the necessary contact with the vehicle structure;
- elements inside the cabin causing minimal injury to the operator, (if there is opportunity to come into contact).

Upon completion of homologation the tractor is required to be fitted with a roll-over protective structure (ROPS). This structure, whose purpose is to provide a survival volume in the event of a rollover, is statically tested according to international standard procedures for the particular tractor type. These tests comprise a series of energy (force–displacement) and force requirements whilst ensuring that the survival volume has not been encroached. Official ROPS tests are performed within Europe according to the Codes of the Organization for Economic and Co-operation Development (OECD) or the equivalent EC Directive. These tests are typically based on the tractor's reference mass, with the only requisite being that it must be greater than or equal to the unladen mass in running order without the driver onboard [10].

MATERIAL AND METHODS

The study was conducted according to the requirements set by the standard ISO 5700 and SAE J 1194, which established a method of static testing and acceptance requirements for cab protective and security frames wheel tractor. In this study, to prescribe standards for the category of tractors with a mass of 800 to 15000 kg and minimum wheel track width greater than 1150 mm was made:

Measurement of the maximum horizontal load means follow:

Examination of the horizontal force acting on the front frame in a plane parallel

the longitudinal axis of the tractor. The offensive power point is located on 170 mm or 116 total width of protective cover. The requirement that the protective frame must satisfy is that the protective frame at overload of the power absorbed energy of E1 = 1666 J while at the same security space operator remain unscathed.

Examination of the horizontal force acting on the side of the upper part of the frame with respect it is certain that he will first touch the ground when the tractor rollover. When the load protective frame has to absorb the energy of E2 = 2082 J while at the same security space operator remain unscathed.

Measurement of the maximum vertical load means examination of the vertical force acting on the front and rear frame without having security operator space remain unscathed.

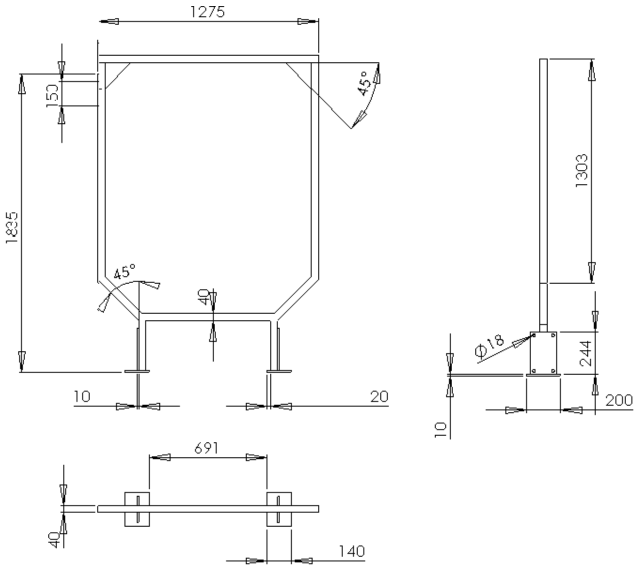

Figure 1. Dimensions of researched protective frame

This paper was carried out examination of the protective frame whose dimensions are shown in Figure 1 Profile dimensions are 40x40x3mm. The frame is hot-rolled steel E235 (EN 10297 - 1 : 2003 Seamless circular steel tubes for mechanical and general engineering purposes. Non-alloy and alloy steel tubes). Crashing force is 38,2 kN.

To simulate the prescribed static testing procedures for ROPS using finite element method Radioss Bulk was used. To create the model Hyper Mesh was used and Radioss Bulk was selected as the phenomena to be simulated involved material deformation beyond its yield strength as well as contact boundary conditions at the point of application of loads Deflection and crushing of beams and poles includes the geometric nonlinearity. Deflection rate was static so no inertia forces were involved. The problem can be model into nonlinear static analysis. The application of load or displacement was applied in steps and at each step the equilibrium should be satisfied. Thus problem can be defined as nonlinear quasi-static analysis [11].

RESULTS AND DISCUSSION

In this crashing test, load was acceptance criteria and acceptance value was crashing force 38,2 kN.

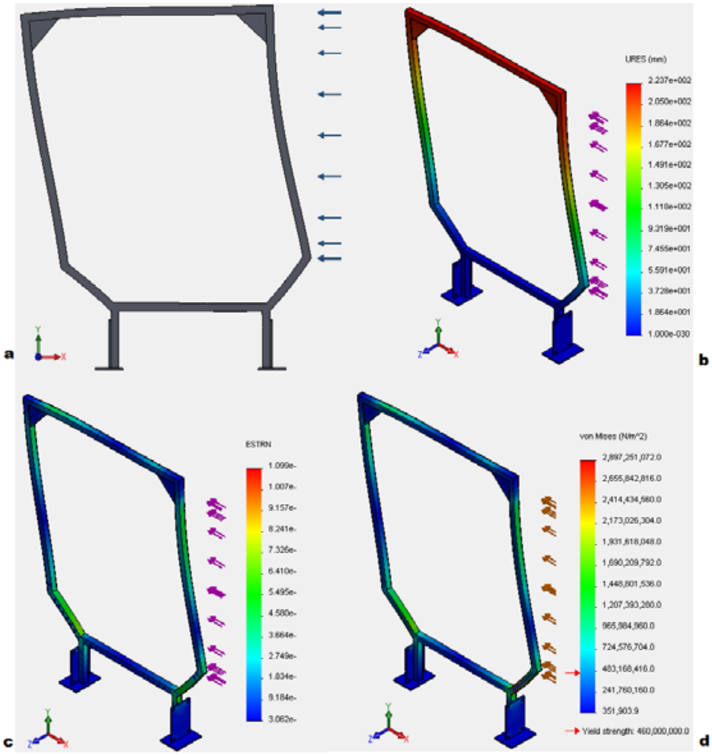

Figure 2. The effect of horizontal load on protective frame (a), view of displacement (b), strain (c) and stress (d)

Fig. 2 shows the result of the horizontal side load test for protective frame. Fig. 3 shows the result of the vertical side load test for protective frame. It is important to note that each load was applied in the sequence shown in Tab. 1 and that subsequent loads were applied following any deformations and stresses sustained during the application of the previous load(s) in the sequence. Once the required energy/load was reached, it was necessary to verify that this was significantly less than the breaking strength of the various structural elements and that no part of the protective frame, while deformed, lead to the infringement of the operator clearance zone or to its invasion by the simulated ground plane. For both side loads depicted in Fig. 2, the maximum stress recovered was significantly lower than the material's breaking strength value, and the operator clearance zone was always protected.

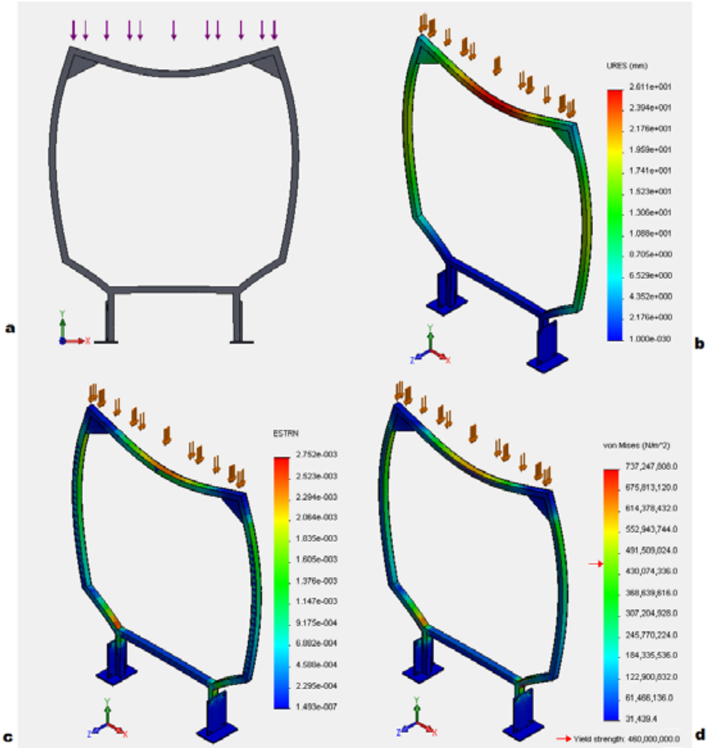

Figure 3. The effect of vertical load on protective frame (a), view of displacement (b), strain (c) and stress (d)

The shown protective frame design process resulted in a permanently fixed roll over protective structure which should provide an adequate level of protection to tractor drivers in the case of a roll over. Moreover, the particular shape of the structure renders working under trees an easier activity and reduces the likelihood of branches being damaged. This has led to an increase in the level of roll over protection offered to drivers of narrow track wheeled agricultural tractors.

The virtual prototyping process and finite element analysis allowed a significant reduction in design costs. Furthermore, the computer aided design (CAD) virtual model helped to take the ergonomic features of the structure into account and the finite element analysis enabled streamlining of the structure, improving its mechanical strength and optimizing the machine production process. Thus, the costly experimental tests have only been carried out on the prototypes which had virtual models that successfully passed the structural analysis. The success factors of the shown protective frame itself can be summarized as follows: reduced tractor overall height; improvement of roll-over protective structure shape, suitable for working under trees or in greenhouses; non-foldable roll-over protective structure.

CONCLUSIONS

Accidents and accidents with farm machinery and tractors are now very common in Serbia, since there is no ongoing training, supporting vocational courses for the proper use and maintenance of these machines.

There are also significant gaps in the knowledge and application of the warp traffic regulations in tractor drivers, as well as irresponsible and undisciplined in the use

tractors and other mobile agricultural machines.

In the future, it is necessary to reduce the number of accidents and accidents at work agricultural machinery and tractors to the smallest possible number. This primarily means providing course of business in agriculture, with the largest

compliance with all prescribed measures and laws pertaining to the protective of machines, and in particular the Law on Road Traffic Safety, when these machines are found in the transport process in public transport areas.

Applying FEM analysis, conducted research and testing protective frame, shows that the requirements defined standards for the protection of the cab or operator with a possible rollover.

Particular focus was given to the appropriateness of using a 'reference' mass associated to the unladen mass as the basis for ROPS strength calculation. A more representative safety criterion may be obtained by linking the energy and force requirements for the ROPS with the maximum laden mass of the tractor. However the mass distribution in working condition can influence the stability/rollover behaviour of the tractor in both positively (increased safety) or negatively (reduced safety). To determine the appropriate energy–mass relationship(s) for ROPS testing additional dedicated research is required.

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MKE ANALIZA SIGURNOSNOG RAMA VOĆARSKOG TRAKTORA PRI PREVRTANJU

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Sažetak: U ovom radu prikazano je jedno konstruktivno rešenje sigurnosnog rama za voćarske traktore i traktore snage do 65 kW koji se koriste u voćarskoj proizvodnji na nagnutim terenima za mašinsko ubiranje (trešenje) koštičavog voća. Prikazani sigurnosni ram može se montirati na postojeće modele traktora, pre svega domaće proizvodnje. U radu je izvršena analiza naponskih stanja posmatranog sigurnosnog rama u režimu neželjenog slučaja prevrtanja traktora. Uobičajena praksa pri ispitivanju i homologaciji sigurnosnih ramova je da se opterete dvostruko većom silom od težine samog traktora. Analiza sigurnosnog rama vršena je pomoću softverskog paketa SolidWorks korišćenjem metode MKE analize. Ram je opterećen silom od 38,2 kN sa bočne strane i sa gornje strane. Dobijeni rezultati ispitivanja ukazuju na zadovoljavajuću bezbednost.

Ključne reči: *traktor, sigurnosni ram, prevrtanje, analiza naponskog stanja, opterećenje.*

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RESULTS OF PRELIMINARY LABORATORY STUDIES AFTER PRE-SOWING ELECTRIC TREATMENT OF PEA SEEDS

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Abstract: In many countries, the possibilities for stimulation of the sowing qualities and yield of cultivars after pre-sowing electric treatment of their seeds have already been identified.

At the University of Ruse, Bulgaria, for more than 20 years studies have been conducted on the pre-sowing stimulation of the sowing qualities of seeds of various agricultural crops that are subjected to pre-sowing electromagnetic treatment.

This article discusses the preliminary results of pre-sowing electric (electromagnetic and electrostatic) treatment of pea seeds.

It has been established that after electro-magnetic or electrostatic pre-sowing treatment it is possible to obtain a stimulant effect on pea seeds. This effect takes place after 14 days of rest from treatment to sowing, and with the other controllable factors has following values:

- for the three-step electromagnetic treatment initial value of the applied voltage is $U_1 = 4$ kV, and duration of treatment $\tau_1 = 5$ s;

- for the electrostatic treatment voltage is $U = 6$ kV, and duration of treatment $\tau = 70$ s.

The treatment applied to pea seeds leads to an increase in the germination capacity by 2,6%, in the length of the sprouts by up to 5,5% and of the rootlets by up to 18,6%, and increase in the mass of the plants by 6,9% as compared to the reference specimen.

***Key words**: three-step electromagnetic treatment, electrostatic treatment, pea seeds, sprouted seeds mass, length of sprouts and rootlets.*

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INTRODUCTION

Vegetables are particularly essential to human health. In this sense, increasing yields of vegetable plants is not insignificant.

It has already been established that there is a possibility for favourable effect on the seeds of some agricultural crops by subjecting them to pre-sowing treatment in different electric fields. Since the increase of yields and food supplies is a primary concern of any society, it is necessary to look for opportunities to increase the fruitfulness of vegetable crops, such as peas.

At the University of Ruse, Bulgaria, for over 20 years now studies have been performed of the pre-sowing stimulation of the sowing qualities of various agricultural crop seeds that are subjected to pre-sowing electromagnetic treatment. Consequently, the values of the controllable factors for pre-sowing electromagnetic treatment of cereals have already been determined - maize [5], wheat [3], cotton [1,2], beans [4].

The purpose of this study is to identify the existing opportunities for the effective influence of electromagnetic and electrostatic fields on the sowing qualities of pea seeds.

MATERIAL AND METHODS

For the purpose of the research, pea seeds of the Bulgarian cultivar "Ran" were used, with declared germination capacity of 90%.

Pea (*Pisum sativum* L.) is a plant in the legumes family (*Fabaceae*). It is rich in the following nutrients: proteins, carbohydrates, fat, fibers, vitamin C and beta carotene, and its energy value is 218 kJ [6]. The foregoing indicates that in its characteristics, the plant is particularly close to beans. This suggests that such treatments should be applied that have brought to results in the pre-sowing electric treatment of beans and other seeds high in fat [4].

For the selection of the values of controllable treatment factors, those factors were taken into consideration which produced the best effect on cotton seeds [1,2] and bean seeds [4].

The plan for the experiment with pea seeds included the options described below:

Treatment options No. 1 (electromagnetic treatment - *EM1*) and No. 2 (electromagnetic treatment - *EM2*) – the treatment of the seeds was performed in a chamber with plate electrodes, as with bean seeds [4]. A three-step electromagnetic treatment was conducted for the purpose, with the seeds being placed in an electromagnetic field created between plate electrodes. At the first step, high voltage was briefly supplied to the electrodes. At every subsequent step, the value of the voltage U [kV], supplied to the electrodes of the chamber, was reduced, while the duration of treatment τ [s], was increased.

The values of controllable factors in treatment options No. 1 and No. 2 are shown in Table 1.

Treatment option No. 3 – the seeds were treated in an electrostatic field (*ES*) with voltage between the electrodes U = 6 kV and duration of treatment τ = 70 s.

Treatment option No. 4 – reference specimen (untreated seeds).

Pea seeds were treated on the following dates:

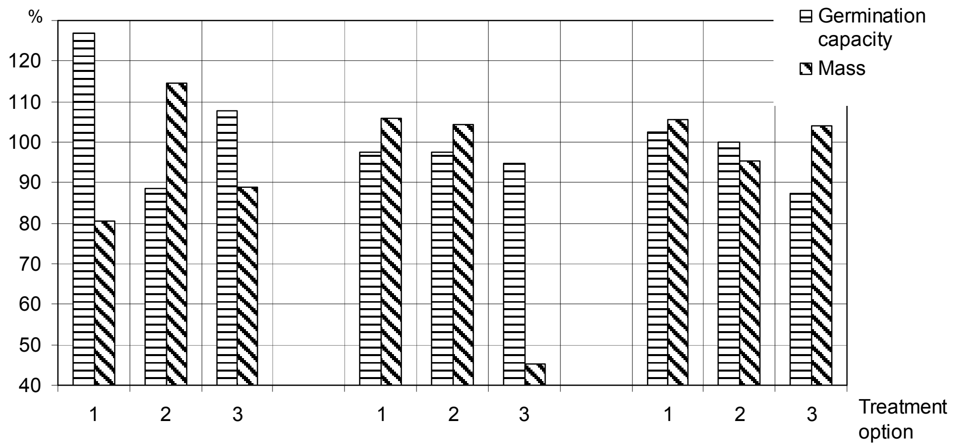
- on 27.03.2010, and set for laboratory examinations in a thermostat on 27.04.2010, i.e. 31 days after treatment;
- on 29.03.2011, and placed for laboratory examinations respectively on 05.04.2011, i.e. 7 days after treatment, and on 12.04.2011, i.e. 14 days after treatment.

Table 1. Three-step electromagnetic treatment of pea seeds by treatment options No. 1 and No. 2

Treatment options	*Treatment steps*					
	First step		*Second step*		*Third step*	
	U_1 [kV]	τ_1 [s]	U_2 [kV]	τ_2 [s]	U_3 [kV]	τ_3 [s]
1 (EM1)	*4*	*5*	*2,5*	*15*	*2*	*25*
2 (EM2)	*5,5*	*5*	*4*	*15*	*3,6*	*25*

RESULTS AND DISCUSSION

The results of the study of laboratory-determined germination capacity and mass of sprouting pea seeds are shown in Fig. 1. The results from Fig. 1 are expressed as a percent (%/R) of the results of the reference (untreated) specimen.



Rest period

31 days	7 days	14 days

Treated in

2010	2011	2011

Figure 1. Results of the study of laboratory-determined germination capacity and sprouted mass

From Fig. 1 it can be concluded that the rest period of 31 days from treatment to sowing (in 2010) had a favorable effect on the germination capacity of pea seeds. The three-step electromagnetic treatment with values of the factors in the first step U_1 = 4 kV and τ_1 = 5 s contributed for the achievement of a germination capacity (option 1) which was 26,9% higher than that of the reference specimen. The increase in the treatment voltage in option No. 2 from 4 kV to 5,5 kV (for the first step), with the same duration of electromagnetic treatment, had a suppressive effect – the germination capacity in this case was only 88,5% of that of the reference seeds.

After the treatment in an electrostatic field (option No. 3) the laboratory-determined germination capacity had increased by 7,7% compared to that of the reference specimen.

Regardless of the improved germination capacity, in the above mentioned treatment options No. 1 and No. 3, the mass of the sprouted plants was lower than that of the reference specimen - 80,6% and 89,0%, respectively. The described situation can be explained with the long period of rest (31 days) of the seeds from the time of treatment until their sowing.

From Fig. 1 it can be concluded that the relatively short period of rest (7 days) in 2011 led to the lower germination of the seeds. It was 97,4%, 97,4% and 94,8%.

The rest period of 12 days in 2011 contributed to a 2,6% increase in the germination of pea seeds and 6.9% increase in the mass of the sprouted plants.

For the seeds germinated in laboratory conditions, the length of their sprouts and rootlets was studied. These results are shown in Table 2.

The analysis of the data in Table 2 indicates that, using the given parameters for the treatment:

- In 2010., with treatment options No. 1 and No. 3, the rest period had a suppressive effect, whereby the resulting lengths of the seed sprouts were respectively 78.3% and 89.8% of that of the reference specimen. Only in Option No. 2 the lengths of the sprouts were 15.1% higher than in the reference specimen. The examination of the length of the rootlets of the treated seeds showed that no statistically significant difference occurred in comparison with the reference specimen;

- The short rest period (7 days) in 2011 showed an even more suppressive effect – the lengths of the sprout and rootlets were 60.2% and 80.2% of those of the reference specimen.

Table 2. Results of the studies of the lengths of sprouts and rootlets of pea seeds after pre-sowing electromagnetic treatment

№	Kind of treat-ment	2010				2011									
		Set after the treatment:													
		31 days				7 days				12 days					
		Sprout		Root		Sprout		Root		Sprout		Root		Germination capacity	
		mm	%/R*	mm	%/R*	mm	%/R	mm	%/R*	mm	%/R*	mm	%/R*	%	%/R*
1	EM1*	13,4	78,3	24,9	103,1	26,9	104,4	66,0	90,5	37,0	105,5	85,7	115,7	100	105,3
2	EM2*	19,6	115,1	23,8	98,4	27,8	97,8	72,1	98,5	33,4	95,3	74,8	100,9	92,5	97,4
3	ES*	15,3	89,8	23,9	99,1	17,1	60,2	58,5	80,2	36,7	104,6	87,9	118,6	85	98,5
4	Reference specimen	18,1	100	24,2	100	28,4	100	72,6	100	35,1	100	74,1	100	95	100

**EM1, EM2 – in accordance with Table 1,*
**ES – electrostatic treatment,*
**%/R – percent of the reference specimen.*

As the seeds rested for 14 days (in 2011) before being sown, in treatment option No. 1 the sprouts were 5,5% longer, the rootlets were 15,7% longer, while in option No. 3 these numbers were 4,6% and 18,6%, respectively. This fact, in combination with the mentioned higher mass of the plants (Fig.1) shows that the pre-sowing electric effect is favorable. After a 7-month drying in laboratory conditions it has been found that the mass of 1 seed (its sprout and rootlets inclusive) is, for the respective treatment options, as follows: No. 1 - 0,193 g (102,1%/R), No. 2 – 0,187 g (98,99%/R) No.3 – 0,199 g (105,3%/R) and for No. 4 (reference specimen) – 0,189g (100%). This comes to show that, except for treatment option No. 2, in the other two options the seeds have accumulated more dry substance during their growth in laboratory conditions than have the seeds from the reference specimen (R).

From the analysis of the obtained results it can be concluded that with the selected values of the controllable factors (voltage and duration of treatment), the effect of the electromagnetic and electrostatic field on the monitored parameters (germination capacity, lengths of sprouts and rootlets, mass of the plants) after a 14-day period of rest is equally favorable.

From the foregoing it can be established that the short (7 days) and the long (31 days) period of rest of the seeds from their treatment to the time of sowing, with unchanged values of the other controllable factors, has an unfavorable effect of the subsequent development of the seeds. This is acts as a restraining factor, since in bad weather conditions the sowing of the seeds in the field might not take place within the prescribed time period of 14 days.

During future research activities it is to be taken into account that the agro-technical time period for sowing pea seeds in Bulgaria is in the second half of February and early March. The analysis of various other studies on different seeds shows that, prior to the said time limit for sowing; activating changes start in the seeds that prepare them for the time of sowing. This, combined with the pre-sowing electric treatments, has a favorable effect on the quality of seeds. In this respect, the time of treatment mentioned (27.03.2010 and 29.03.2011) is after the agro-technical time limit.

CONCLUSIONS

1. It has been established that after an electromagnetic or electrostatic pre-sowing treatment it is possible to produce a stimulant effect on pea seeds. This is achieved by allowing a rest period of 14 days between the treatment and the sowing, and values of the other controllable factors, as follows:
   - for the three-step electromagnetic treatment: initial values of the applied voltage U_1 = 4 kV and duration of treatment τ_1 = 5 s;
   - for the electrostatic treatment: voltage U = 6 kV and duration of treatment τ = 70 s.

The said kinds of treatment result in an increase in the germination capacity by 2,6%, increase in the length of sprouts by up to 5,5%, in the length of rootlets by up to 18,6% and in the mass of plants by up to 6,9%, as compared to the reference specimen.

2. For the shorter rest period (7 days), and for the longer rest period (31 days), with the same values of the other controllable factors of treatment, a

suppressive effect on the pea seeds has been observed. The same effect takes place when applying higher voltage at the first treatment step, i.e. $U_1 = 5{,}5$ kV.

3. A study of the pre-sowing electric treatment of pea seeds is to be carried out before the agro-technical time limit for sowing them.

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REZULTATI PRELIMINARNIH LABORATORIJSKIH ISPITIVANJA ELEKTRIČNOG TRETMANA SEMENA GRAŠKA PRE SETVE

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Sažetak: U mnogim zemljama su već identifikovane mogućnosti za stimulisanje setvenog kvaliteta i prinosa sorti posle električnog tretmana semena pre setve.

Na Univerzitetu u Ruse, Bugarska, više od 20 godina se sprovode istraživanja stimulacije kvaliteta semena, elektromagnetnim tretmanom pre setve, kod raznih poljoprivrednih kultura.

Ovaj rad predstavlja preliminarne rezultate električnog (elektromagnetnog i elektrostatičkog) tretmana semena graška.

Utvrđeno je da je posle elektro – magnetnog ili elektrostatičkog tretmana pre setve moguće postići stimulativni efekat na seme graška. Ovaj efekat se ispoljava 14 dana posle tretmana za setvu, a drugi kontrolisani faktori imaju sledeće vrednosti:

- za tro-stepeni elektromagnetni tretman inicijalna vrednost primenjenog napona je $U_1 = 4$ kV, a vreme trajanje tretmana $\tau_1 = 5$s;
- za elektrostatički tretman napon je $U = 6$ kV, a vreme trajanje tretmana $\tau = 70$ s.

Tretman primenjen na seme graška dovodi do povećanja kapaciteta klijanja od 2,6%, dužine klijanaca do 5,5% i korena do 18,6% i povećanje mase biljaka od 6,9 %, u poređenju sa referentnim uzorkom.

Ključne reči: *tro-stepeni elektromagnetni tretman, elektrostatički tretman, seme graška, masa klijavog smena, dužina klijanaca i korena.*

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ENERGY CONSUMPTION AND ENERGY EFFICIENCY OF DIFFERENT TILLAGE SYSTEMS IN THE SEMI-ARID REGION OF AUSTRIA

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Abstract: Tillage in conventional cropping systems requires a high amount of direct energy in form of fuel and influences the energy efficiency of the production system. The fuel consumption was measured in three conventional tillage systems (plough, heavy cultivator and sub-soiler, integrated system) and two conservation tillage systems (mulch seeding, no-tillage) with a high-performance flow-meter, which was integrated in a four wheel driven tractor (92 kW). The tillage trials were carried out on a *Chernozem* soil with silty loam in the semiarid region of Austria (mean temperature: 9.8°C; mean rainfall: 546 mm). Moreover the total energy efficiency was calculated from the energy input (direct: fuel; indirect: seeds, fertilizer, pesticides and machines) and energy output (heat value) of winter wheat. The highest fuel consumption in the soil tillage was measured in the conventional tillage with plough (39.9 $l \cdot ha^{-1}$), where 18.8 $l \cdot ha^{-1}$ results from the plough. The lowest fuel consumption was in the no-tillage system, where 5.9 $l \cdot ha^{-1}$ fuel for seeding was required. The total fuel consumption can be reduced between 33% and 50% with conservation tillage in comparison to conventional tillage with plough. The best energetic parameters (energy and fuel intensity, net energy and energy efficiency) were realised in the conservation tillage systems.

Key words: *tillage system, fuel consumption, energy efficiency, energy intensity, plough, no-tillage*

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INTRODUCTION

Farming – from beef, pig, poultry or dairy and crops – has become increasingly mechanized and requires significant energy inputs at particular stages of the production cycle to achieve optimum yields. In accordance to Factor Five [16], the agricultural Sector has the potential to achieve a Factor 10 - 100 improvement in resource productivity. Due to increasing fuel prices, energy efficiency in plant production became an increasing awareness [12].The awareness in saving of direct energy has grown rapidly in this sector due to continues increase in energy prices (for example fuel) in the last couple of years. Reducing the fuel consumption in agriculture is a complex am multi-factorial process, where farm management plays a key factor in the fuel consumption reduction programs [13].

The energy input in plant cropping can be categorised into two main groups [6]: direct energy (fuel for machinery, heating oil and electricity for drying processes or conveyors) and indirect energy: (process energy for the production on "annual" facilities e.g. fertilizer, pesticides, seeds and "perennial" facilities e.g. farm machinery, farm buildings). In a conventional cropping system the greatest energy consumer is soil tillage [17]. Fuel consumption of soil tillage is correlated with the intensity of soil tillage. In comparison to conventional tillage systems with plough for primary tillage, the fuel consumption can be significantly reduced with conservation tillage systems [10]. Additional soil related parameters e.g. soil texture and organic matter content influences the fuel consumption in soil tillage [10, 9]. Depending on the soil constitution the fuel consumption increases per centimetre ploughing depth between 0.5 and 1.5 $l \cdot ha^{-1}$ [4, 7, 11]. Besides fuel saving in conservation tillage systems, there is a higher soil water storage capacity in semi-arid regions [3].

The aim of the research was to analyse the influence of three conventional tillage systems and two conservation tillage systems on the fuel consumption and energy efficiency for wheat production in a semiarid region of Austria (Marchfeld in Lower Austria).

MATERIAL AND METHODS

A long term trial for soil tillage since 1997 at the experimental station of the University of Natural Resources and Life Sciences - Vienna (BOKU) at the location Gross Enzersdorf (Tab. 1) was used for the measurement of fuel consumption and determination of energy efficiency. Each tillage system (Tab. 2) is designed in randomized plots in a fourfold repetition. The size of plots (60 m x 24 m) allows the cultivation with tillage implements, which are usually used on arable farms.

Table 1. Description of the trial locations in Lower Austria [15]

Location	*Gross Enzersdorf (lower Austria); 153 m above sea level*
Average temperature	*9.8 °C*
Average rainfall	*546 mm*
Classification of soil texture	*silty loam*
Type of soil	*chernozem*

Table 2. Tillage systems with operations

Tillage System	*Description*
Conventional tillage with plough (Conventional 1)	*Heavy cultivator for stubble field skimming (3 m, 5 cm*); 2x4-mouldboard plough (1.6 m, 25 cm); Power harrow (3 m, 5 cm); Seeding machine (3 m, 3 cm)*
Conventional tillage with heavy cultivator and subsoiler (Conventional 2)	*Heavy cultivator for Stubble field skimming (3 m, 5 cm); Subsoiler** (3 m, 35 cm); Heavy cultivator (3 m, 20 cm); Power harrow (3 m, 5 cm); Seeding machine (3 m, 3 cm)*
Conventional tillage –integrated Every four years: plough instead of cultivator (Conventional 3)	*Heavy cultivator for Stubble field skimming (3 m, 5 cm); Heavy cultivator (3 m, 10 – 15 cm); Resp. 2x4-mouldboard plough (1.6 m, 25 cm); Power harrow (3 m, 5 cm); Seeding machine (3 m, 3 cm)*
Conservation tillage – mulch seeding (Conservation 1)	*Heavy cultivator for Stubble field skimming (3 m, 5 cm); Heavy cultivator (3 m, 8 cm); Seeding machine (3 m, 3 cm)*
Conservation tillage – direct seeding (Conservation 2 – No tillage)	*Direct drilling machine with disc coulters (3 m, 2 cm)*

** first value: technical working width, second value: mean working depth*
***sub-soiler is used every fourth year*

For all experiments a four-wheel drive tractor (Steyr 9125, CNH, St. Valentin, Austria) with an engine power of 92 kW (DIN) was used. The measurement of the fuel consumption was done with a high-performance flow-meter (AVL PLU 116H[1]), which was integrated in the fuel system of the tractor. The volumetric fuel consumption was continuously measured with an error rate of 1 % without pressure drop between inlet and outlet (Δp = 0). The signals of the radar-sensor, transmission sensor, inductive sensor and flow-meter (Tab. 3) were scanned with a scan-rate of 1 Hz in a multi-channel data-logger (Squirrel Datenlogger 2020).

Table 3. Process parameters and their measurements

Process parameters	*Measurement engineering*
Vehicle speed v *[km·h⁻¹]*	*Radar sensor generates a rectangular signal (130 pulses* m^{-1} *= 27.8 Hz/[km·h⁻¹]*
Wheel speed v_0 *[km·h⁻¹]*	*Transmission sensor (inductive transducer), generates a 0.4 - 3.8 V AC signal*
Engine speed n_E *[rpm]*	*Inductive sensor generates a rectangular signal between 0 - 12 V AC signal*
Fuel consumption B *[l·h⁻¹]*	*Flow meter (PLU 116 H), generates a digital rectangular signal between 22 - 2800 Hz*

The area-specific fuel consumption (B_A) is defined by Eq. 1.

$$B_A = B \cdot T_A \tag{1}$$

where:
B_A [l·ha^{-1}] - area-specific fuel consumption,
B [l·h^{-1}] - fuel consumption,
T_A [h·ha^{-1}] - technical field operation time.

The calculated area-specific fuel consumption (B_A in l·ha^{-1}) does not consider the fuel consumption during turning at the headland. This parameter allows the comparison of soil tillage devices without influence of field shape and field size.

The technical field performance (C_A) is defined by Eq. 2.

$$C_A = b \cdot v \cdot 0.1 \tag{2}$$

where:
C_A [ha·h^{-1}] - technical field performance,
b [m] - technical working width,
v [km·h^{-1}] - vehicle speed,
0.1 [-] - conversion factor.

The technical field operation time (T_A) is defined by Eq. 3.

$$T_A = \frac{1}{C_A} \tag{3}$$

For the energy analysis, the energy inputs via fuel was calculated with the lower heat value of 35,2 MJ·l^{-1} diesel fuel. The energy equivalents for fertilizer, pesticides and machines were taken from [6, 2, 14]. The energy output of grain was energetically evaluated with the heat value of 18.3 MJ·kg^{-1} dry matter winter wheat.

RESULTS AND DISCUSSION

The measured technical parameters area-specific fuel consumption (l·ha^{-1}) and technical field performance (ha·h^{-1}) for the different soil tillage operations are shown in Tab. 4.

Soil tillage with plough has the highest fuel consumption of 18.8 l·ha^{-1}. With the cultivator can be reduced about 50 %. Turning at the headland was conventional done in the so-called „swallowtail-shape". The mean working time requires between 21 and 35 sec. with an average fuel consumption of 5.0 and 5.8 l·h^{-1}. This technical parameters allows the modeling of the fuel consumption in dependence of field size and field sharp.

The fuel consumption depends also on the soil texture. On a soil with loamy clay, the measured fuel consumption for ploughing was 35.6 l·ha^{-1} [10].

Table 4. Mean measured technical process parameter for different field operations

Field operations	*Fuel Consumption* *[l·ha⁻¹]*	*Technical field performance [ha·h⁻¹]*	*Working time requirement for one turning event* [s]	*Fuel consumption at turning [l·h⁻¹]*
Ploughing (25 cm)	*18.8*	*1.03*	*35*	*5.0*
Subsoiling (35 cm)	*9.4*	*2.16*	*30*	*5.8*
Cultivating (20 cm)	*9.4*	*2.19*	*26*	*5.0*
Cultivating (8 cm)	*6.7*	*2.71*	*23*	*5.0*
Power harrowing	*8.6*	*2.31*	*22*	*5.6*
Seeding	*6.3*	*2.46*	*33*	*5.3*
Stubble field skimming	*5.6*	*2.85*	*21*	*5.0*

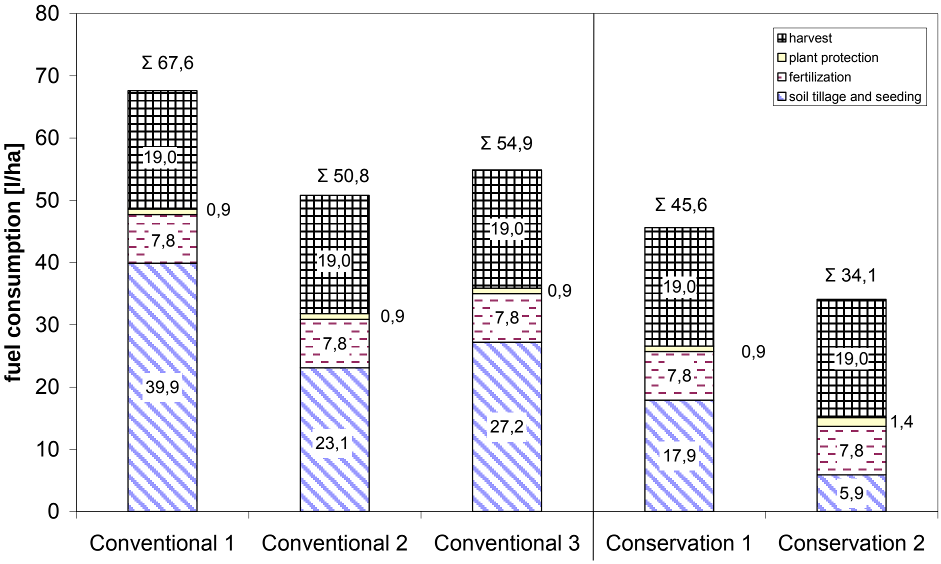

Figure 1. Fuel consumption of the different soil tillage systems for winter wheat cropping (Fuel consumption for fertilization, plant protection and harvest is calculated by means of data from The Association for Technology and Structures in Agriculture (KTBL), [8]

The total area-specific fuel consumption (l/ha), without consideration of the fuel consumption at the turning are shown in Fig. 1. For the tillage system with plough (Conventional 1), about 58 % of the total fuel consumption is caused by soil tillage and seeding. If the plough is substituted by an heavy cultivator (Conventional 2) the fuel consumption for soil tillage can be reduced by 42 % to 23.1 l/ha. The integrated tillage system (Conventional 3) is between Conventional 1 and 2. Conservation tillage systems have the lowest fuel consumption, which is caused by shallow soil tillage (Conservation

1) and no tillage (Conservation 2). Besides the reduction of the fuel consumption, also the working time requirement decreases with the shift from conventional tillage to conservation tillage [15]. For the conservation tillage systems, the working time requirement can be reduced between 48 and 81% [15].

The Tab. 5 about the energy analysis for winter-wheat indicates, that more than 75% of the total required energy belongs to the indirect energy form (seeds, fertilizer, herbicides and machine).

The main indirect energy consumer is the nitrogen fertilizers. This share of indirect energy to total energy was also found in the investigations for conventional crop production system in Canada [5].

Table 5. Energy analysis for wheat production in different soil tillage systems at the location Gross Enzersdorf (soil texture: silty loam)

	Conventional tillage			Conservation tillage	
	1	2	3	1	2
Direct Energy input [$MJ \cdot ha^{-1}$]	2380	1788	1932	1605	1200
Fuel for soil tillage (Fig. 1)	1404	813	957	630	208
Fuel for fertilizer application	275	275	275	275	275
Fuel for pesticide application +1 glyphosate application in Conservation tillage 2	32	32	32	32	49
Fuel for harvest (combine)	669	669	669	669	669
Indirect Energy input [$MJ \cdot ha^{-1}$]	7042	7030	7013	7033	7109
Seeds (160 $kg \cdot ha^{-1}$)	880	880	880	880	880
Fertilizers (Ø 120 $kg\ N \cdot ha^{-1}$)	4874	4874	4874	4874	4874
Herbicides + 1 glyphosate application (2 $l \cdot ha^{-1}$) in Conservation tillage 2	675	675	675	675	805
Machines	612	600	583	603	550
Total Energy input [$MJ \cdot ha^{-1}$]	9422	8818	8945	8638	8609
Ratio Direct Energy:Indirect Energy	25:75	20:80	22:78	19:81	14:86
Wheat yield*) [$kg \cdot ha^{-1}$], 89 % DM	4636	4788	4969	4842	5117
Energy output_grain [$MJ \cdot ha^{-1}$]	72964	75347	78205	76198	80539
Energy intensity [Input_ $MJ \cdot kg^{-1}$ wheat]	2.03	1.84	1.80	1.78	1.68
Fuel intensity [$l\ fuel \cdot t^{-1}$ wheat]	14.58	10.60	11.04	9.41	6.66
Output-Input = Net energy [$MJ \cdot ha^{-1}$] (grain)	63542	66529	69260	67560	72230
Output/Input = Energy efficiency (grain)	7.70	8.54	8.74	8.82	9.69

*) mean wheat yield from the year 1998, 2000, 2002, 2004, 2007 and 2009

The tillage systems without plough (Conventional 2 and 3; Conservation 1 and 2) realized higher wheat yields in the investigated six years, which was explained by the improved water storage capacity especially in the periods of draught. The highest yield was measured in the no-tillage system.

The energy analysis for wheat production indicates that the conservation tillage systems had the best energetic parameters (energy and fuel intensity, net energy and energy efficiency) at this site with semi-arid climate. The lowest energy intensity of 1.68 $MJ \cdot kg^{-1}$ wheat was calculated in the no-tillage system, which is caused by the lower direct energy input of fuel and the highest mean yield of wheat (5.117 $kg \cdot ha^{-1}$). The conservation tillage system 1 with mulch seeding has the second best energy intensity and energy efficiency.

CONCLUSIONS

Fuel consumption in cereal cropping is significantly influenced by the soil tillage system. The reduction of tillage intensity in conservation soil tillage systems results in a decrease of fuel and working time. Conservation tillage systems conserve the soil structure and especially in the semi-arid region the soil water content, which is a adaptation contribution to climate change.

The shift from soil tillage systems with plough to conservation tillage systems reduces the direct energy input and improves the energy efficiency in the semi-arid region.

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POTROŠNJA ENERGIJE I ENERGETSKA EFIKASNIOST RAZLIČITIH SISTEMA OBRADE ZEMLJIŠTA U POLU-SUŠNOM REGIONU AUSTRIJE

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Sažetak: Obrada zemljišta u konvencionalnim sistemima ratarenja zahteva veliku količinu direktne energije iz goriva i utiče na energetsku efikasnost proizvodnog sistema. Potrošnja goriva je merena u tri konvencionalna sistema obrade (plug, teški kultivator i podrivač, integrisani sistem) i dva konzervacijska sistema obrade (malč setva, bez obrade) sa meračem protoka visokih performansi, koji je bio integrisan u traktor sa pogonom na sva četiri točka (92 kW). Probe obrade su izvedene na černozemu sa ilovastim sedimentom polu-aridnom regionu Austrije (srednja temperatura 9.8°C; srednji nivo padavina 546 mm). Ukupna energetska efikasnost je izračunata iz energetskih unosa (direktni: gorivo, indirektni: seme, đubrivo, pesticidi i mašine) i energetskih izlaza (toplotna vrednost) ozime pšenice. Najveća potrošnja goriva u obradi zemljišta je izmerena u konvencionalnoj obradi plugom (39,9 $l \cdot ha^{-1}$), gde je 18.8 $l \cdot ha^{-1}$ rezultat pluga. Najniži potrošnja goriva je u sistemu bez obrade, gde je bilo potrebno 5,9 $l \cdot ha^{-1}$ goriva za setvu . Ukupna potrošnja goriva može da se smanji između 33% i 50% sa konzervacijskom obradom u odnosu na konvencionalnu obradu plugom. Najbolji energetski parametri (energetski intenzitet i gorivo, neto energija i energetska efikasnost) realizovani su u konzervacijskim sistemima obrade zemljišta.

Ključne reči: *system obrade, potrošnja goriva, energetska efikasnost, energetski intenzitet, plug, bez obrade*

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INVESTIGATION OF MICROSTRUCTURE, ADHESION STRENGTH AND WEAR RESISTANCE OF COATINGS BEING OBTAINED WITH COMBINED METHOD

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Abstract: This paper deals with a state-of-the-art two staged coating technology involving Cold Gas Dynamic Spraying (CGDS) followed by treatment of the sprayed layer by Micro Arc Oxidation (MAO). This technology provides good physical and mechanical properties and high performance of coatings obtained. Experimental study data on the used process parameters and their impact on the performance of obtained coatings are presented. Test data relating to the properties of the coatings obtained, and general technological recommendations on practical application of the proposed technology are provided.

Key words*: micro arc oxidation, gas dynamic spraying, element, coating, wear resistance, microstructure, morphology, adhesion strength*

INTRODUCTION

It is known that higher wear resistance of most machine parts is achieved by using coatings with required parameters. Wear of machine and equipment components is known to be 0,1 – 3,0 mm for different types of materials. Worn surfaces are industrially repaired by various methods, such as using oversize spare parts; welding and surfacing; spraying; plastic straining, various electrochemical processes, and other types of hard surfacing [1,2]. Unfortunately, these feature a lot of major disadvantages:

- they fail to always ensure the required endurance of friction pairs;

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- certain materials (and technologies) used are limited by strict sanitary standards, which particularly concerns surfaces coming in contact with food environment and food products;
- high complexity and high cost of the technological equipment used;
- technologies are inconsistent with ecological standards and require costly special-purpose protection.

The most promising of the current repairing technologies are certain types of thermal spraying, and fast developing micro arc oxidation. Studies of the special nature of thermal spraying and micro arc oxidation for various types of materials, including steels and valve metals have revealed a number of benefits and flaws.

Thermal spray technology does not necessarily ensure efficient coatings, which would be highly resistant to thermal cycling due to their high friability and poor adhesion. Furthermore, high porosity and roughness of coating surface require mechanical treatment of articles aimed to preserve their sizes and ensure adequate quality of surface. Cold gas dynamic spraying, which is a relatively new method of coating, has been widely used since recently [3, 4]. With CGDS, powder particles (a plastic metal powder or composite powder with less than 50 μm particles []) are accelerating up to 300-1,200 m/s by a heated Laval nozzle-generated ultrasound high-pressure gas jet. This creates a solid high-adhesive (35-40 MPa) coating of low strength metals by using relatively simple equipment [5, 6].

As regards micro arc oxidation [7, 8], it enables high-adhesive oxide-ceramic layers with adequate wear- and heat resistance properties depending on porosity and roughness of the treated material in order to maintain the initial dimensions and geometric parameters of detail and, possibly, to rule out subsequent mechanical treatment of the coated details. However, MAO is used in valve metals alone, and cannot be applied in treatment of steels used to produce most of the machine and equipment parts.

This paper deals with the results of consequent application of both of these methods (CGDS and MAO) and the development of combined repairing and hardening technology to integrate their advantages. The resulting technology is recommended for industrial use, including repairing of details made of aluminum alloys, alloys steels, carbon steels and corrosion-resistant steels. Expected increase in life cycle of reconditioned and hardened articles is about 150-200% versus brand new parts.

MATERIAL AND METHODS

Coatings were generated on square coupons (50x50x4 mm) of aluminum UNS A91200 and steel UNS G43400.

Aluminum coating has been sprayed on samples by means of low-pressure cold gas dynamic spraying system (below 0,9 MPa), Dimet-405 (Fig. 1). Powder A80-13 (Al – base, Al_2O_3, Zn; Dimet) have been used. Compressed air was used as an actuation gas. Before spraying, the samples have been cleaned up and activated by sand blasting using 200 mesh Al_2O_3 at the same equipment.

The MAO device contains a 40 kW AC power supply with a 50 Hz modulation, an electrolyte bath, a stirring and cooling system. Current density was 15-20 $A \cdot dm^2$.

The electrolyte consisted of an aqueous solution of sodium silicate (10-12 $g \cdot l^{-1}$) and potassium hydroxide (1-2 $g \cdot l^{-1}$).

Figure 1. General view of the device "Dimet-405"

Adhesion strength of the resulting coatings was tested at PosiTest Pull-Off Adhesion Tester (DeFelsko Corporation, USA) according to ASTM D4541-95e1 [9], ASTM C 633 – 79 [10].

Metallographic tests were conducted at ZEISS Axiolab A equipped with an image review system and SEM JEOL 35CF.

Coating thicknesses (total thickness of coating and oxidized layer thickness) were measured using a digital CM-8825 (Ferrous & Non Ferrous type) coating thickness gauge, which coating thickness with an accuracy of 0,1 μm.

Comparative coating wear-resistance tests (both for cold gas-dynamic spraying and MAO) were conducted according to ASTM G 99 – 95a [11] using «rotating disk – fixed pin» pattern at constant load and rotation speed. Non-coated aluminum alloys (UNS A04131, UNS A03561 and DIN G-AlSi12) and CGDS-formed coating with no MAO hardening were used as a reference. Tests were lasting for 200 hours.

Microhardness of the resulting coating was checked at microhardness tester Buehler Micromet Microhardness 2103.

RESULTS AND DISCUSSION

Morphology and microstructure of coatings

The principal characteristics of coatings being obtained by means of CGDS (Cold Gas Dynamic Spraying) is that they are the composite material consisting of metal matrix and separate ceramic particle incorporated into it [11].

Fig. 2 shows typical coating formed by Gas Dynamic Spraying on steel support.

On the photo the interface between support (steel (1)) and sprayed coating (2) is clearly seen. Along the whole interface there are no clearances, cavities and foreign inclusions. The presence of the included aluminum oxide particles (position 3) are traced with definite regularities in the surface layer of the support. It is noteworthy to stress that aluminum oxide particles are rather uniformly distributed along the coating thickness.

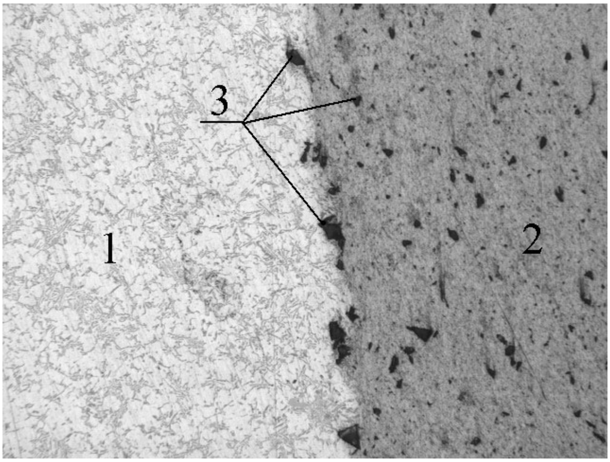


Figure 2. Microstructure of coating being obtained by Gas Dynamic Spraying from powder material of type A-80-13, 200^x 1 – steel support, 2 – coating 3 – particles of aluminum oxide

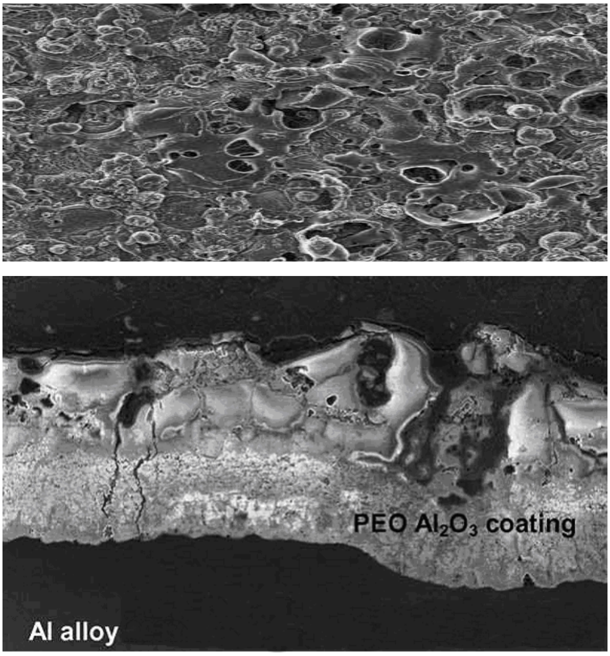


Figure 3. Morphology (up) and microstructure (down) of coatings formed by Micro Arc Oxidation Magnification 600^X u 400^X

It affirms their participation in creation of the main mass of the coating. Zinc particles in the coating composition are hardly differentiated probably because of their small percentage composition in a total mass of the sprayed powder material (nearly 15%). On the ground of the mentioned above it is possible to conclude that the coatings obtained by CGDS consist of tightly packed particles uniformly covering the surface.

Fig. 3 presents morphology and typical microstructure of coatings being formed with micro arc oxidation on the spayed surfaces. Metallographic sample analysis showed that the obtained oxide ceramics layer on the sprayed surface is more consistent close to aluminum support. On the external surface it has greater porosity and consists of numerous melted areas in the form of micro craters and drop-shaped traces of melting of oxide film substance and electrolyte components. The traces of micro discharges localization in the form of melted craters can be seen in pores. It is possible to conclude that at Micro Arc Oxidation oxide ceramics layer with developed surface in aluminum support is formed.

Adhesion Strength of Coatings

Results of adhesion studies on CGDS coatings [12, 16] on aluminum alloys and carbon alloy steels are shown in Fig. 4.

Particles of the sprayed powdered material are speeding up, as air pressure is rising in CGDS plant spraying chamber, and therefore an maximum adhesion strength of coatings is achieved (Fig. 4a). The maximum possible pressure in the spray chamber depends on design features of the plant.

As air heating temperature pressure is rising, adhesion strength of coatings reduces (Fig. 4b). This is attributed to higher activity of sprayed particles. Therefore, not only the particles with an adequate kinetic energy will adhere onto the sprayed surface, but also the particles with lower kinetic energy and higher temperature.

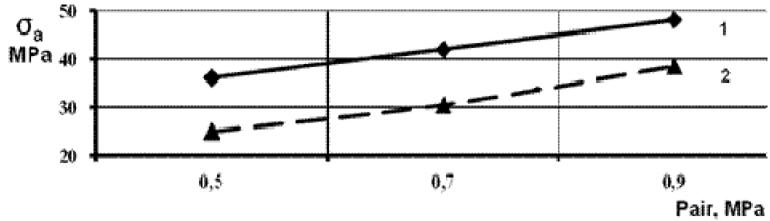
Adhesion strength of CGDS and gas-flame sprayed coatings is gradually rising proportionate to the increase in roughness of the sprayed surface. The maximum adhesion is achieved at Rz = 60-120 μm.

The experimental data obtained support our theoretical assumption that solid particle – substrate interaction associated with CGDS is not only dependent on heating temperature and air pressure in the spraying chamber, but also on sprayed particle size (Fig. 4c). There are always particles of such size which would ensure their detachment from the substrate, whatever their speed may be, even if the maximum possible number of links has been created at contact.

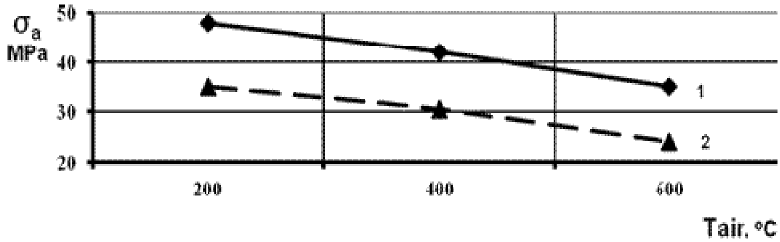
This evaluation of coating adhesion strength shows that under the given interaction conditions, particles with elastic energy and adhesion energy have the same order of magnitude, with elastic energy of compression gaining a major importance in solid spraying. Therefore, relatively small fractions of sprayed powder shall be used to alleviate the effect of elastic rebound of particles (≤ 60 μm).

To maintain adequate strength properties of coatings created by CGDS and MAO hardening, transition area between the substrate and MAO-hardened layer shall be at least 70…100 μm thick.

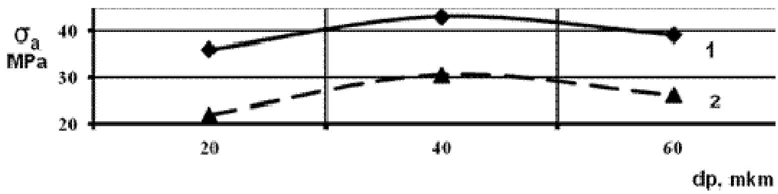
Quantitative study of adhesion strength for MAO coatings formed in $KOH\text{-}Na_2SiO_3$-type electrolyte showed no blistering or stripping of coatings on control surfaces, regardless of the type of electrolyte, current density, and oxidation time.



a)



b)



c)

Figure 4 – Adhesion strength – CGDS mode dependence
(1 – aluminum substrate; 2 – steel substrate):

a) dependence on air pressure in the spraying chamber
(air heating temperature (const) – 400 °C);
b) dependence on air heating temperature in the spraying chamber
(air pressure in the spraying chamber (const) – 0,7 MPa);
c) dependence on powdered material fraction
(air pressure in the spraying chamber– 0,7 MPa, spraying distance– 15 mm,
air heating temperature – 400 °C).

Abrasive Wear Tests

Results of wear resistance studies for proposed coatings are shown in Fig. 5. According to [13-16], wear resistance of hardened CGDS coatings is 7 – 7,8 - fold higher than of non-hardened coatings, and 5 – 6 - fold higher than of aluminum alloys.

Analysis of the data obtained shows that wear rate of friction couples with oxide-ceramic coated samples is 6-fold lower than of reference friction couples with CGDS-formed coating without hardening, and 4,1…5,2-fold lower than the wear rate of friction couples with aluminum samples (depending on the type of alloy).

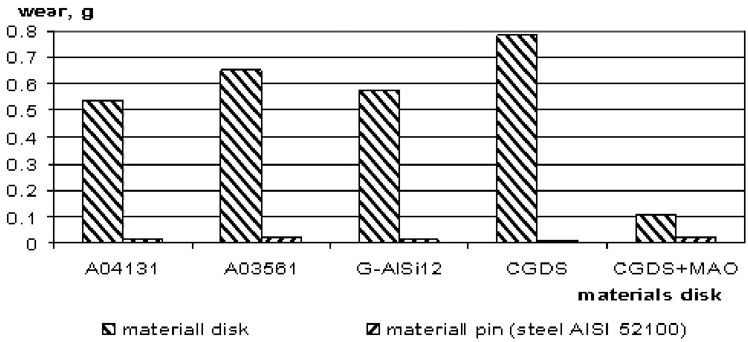


Figure 5. Wear values for "disk-pin" samples
(CGDS – gas dynamic spraying;
CGDS+MAO – gas dynamic spraying and micro arc oxidation)

CONCLUSIONS

This combined technology enables to form hardened high resistant and adhesion strong layers on steel (aluminum) surfaces.

The study supports efficacy and feasibility of using combined technology that consists of creating a powdered aluminum-containing layer on metal surfaces (including non-valve metals) by means of CGDS followed by sprayed layer oxidation using MAO, with required adhesion strength obtained by treatment modes, and structural status of the working surface attributed to electrolyte composition and porosity of the interim powder sub-layer, which in its turn depends on its thickness and spraying modes.

All performance parameters obtained are conformant to standard requirements.

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ISTRAŽIVANJE MIKROSTRUKTURE, ADHEZIONE SILE I OTPORA HABANJU PREMAZA NANETIH KOMBINOVANIM METODOM

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Sažetak: U radu sa razmatra najsavremeniju dvostepenu tehnologiju nanošenja premaza koja uključuje dinamički sprej hladnog gasa (CGDS) praćen tretiranjem nanetog sloja spreja mikro-lučnom oksidacijom (MAO). Ova tehnologija daje dobre fizičke i mehaničke osobine i visoke performanse dobijenih premaza. Predstavljeni su eksperimentalni rezultati istraživanja parametara ovih procesa i njihov uticaj na performanse dobijenih premaza. Dati su rezultati testiranja svojstava dobijenih premaza i opšte tehnološke preporuke o praktičnoj primeni predložene tehnologije.

Ključne reči*: mikro-lučna oksidacija, dinamički sprej gasa, element, premaz, otpor habanju, mikrostruktura, morfologija, adheziona sila*

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DEVELOPMENT AND COMPARATIVE STUDY OF CAST IRON RASP BAR AND NYLON RASP BAR THRESHING CYLINDERS FOR PADDY THRESHING

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Abstract: Two types of threshing cylinders, namely cast iron rasp bar threshing cylinder and nylon rasp bar threshing cylinder, were developed and fitted with portable paddy thresher. Each threshing cylinder was tested for its performance in terms of threshing efficiency and grain damage at different levels of factors: concave clearance (15, 20, 25 mm), cylinder peripheral speed (11.7, 14.1, 16.5 $m \cdot s^{-1}$), grain moisture (13.5%, 16.5%, 19.5%) and feed rate (200, 400, 600 $kg \cdot h^{-1}$). Comparing the maximum threshing efficiency, minimum grain damage in different combinations was achieved at 20 mm concave clearance, 16.5 $m \cdot s^{-1}$ cylinder speed, 13.5% moisture content and at a feed rate of 600 $kg \cdot h^{-1}$. The grain damage occurred at this combination was 2.76% and 1.73% respectively, for cast iron rasp bar and nylon rasp bar threshing cylinders. The threshing efficiency occurred at this combination was 99.95% and 99.93% respectively, for cast iron rasp bar and nylon rasp bar threshing cylinders.

Key words: *paddy threshing, nylon rasp bar, cast iron rasp bar, grain damage, threshing efficiency.*

INTRODUCTION

Threshing is the detachment of paddy grain from the rice plant by striking, rubbing, squeezing or a combination. Impact is the most important phenomenon responsible for

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loosening of grain from the ear head, in all the threshers. Various designs of threshing mechanisms have been developed to thresh cereals crops and to obtain maximum threshing efficiency with reasonably less grain damage. [1] Reported that mechanical threshing caused more damage than any other methods of indigenous origin. The maximum difference in percent of damage was observed between mechanical threshing and hand threshing, 16.50% for rice. Further, they reported that higher the impact, the greater was the mechanical injury and higher the moisture content of the seed, greater was the mechanical injury. The threshing mechanism of mechanical threshers utilizes either rasp bars or wire loops as a functional component of the threshing mechanism. Concave clearance and cylinder peripheral speed are the operational parameters associated with threshing mechanism. In order to investigate the compatibility of wire loop and rasp bar cylinders, a comparative study was conducted for threshing rice crop. Authors in [2] and [3] stated that rasp bar mechanism will give best result. According to [4] rasp bar type thresher was the best among different methods of threshing. Authors in [5] used rubber lined rasp-bar for threshing wheat and later on this practice was discontinued as synthetic material was found withstand without high rate of wear. Eremin (1977) [6] studied the damage sustained by seeds from machines and working parts, such as threshing drums of various materials. He recommended reduction of mechanical damage by use of plastic coating on the contact surfaces. In commercial rasp bar cylinder, the bar was made from cast iron so the grains get more damage while threshing between the concave and rasp bar. In this concern we introduce nylon rasp bar instead of cast iron rasp bar to get more effective threshing with damage free threshing. The nylon rasp bar's abrasive surface was smoothen, less weight and equal strength when compare with cast iron bar.

MATERIAL AND METHODS

Cylinder- concave mechanisms

Study included functional effectiveness in relation to paddy threshing, with two types of experimental threshing cylinders. Namely, nylon rasp bar and cast iron rasp bar threshing cylinders were fabricated and are depicted in Fig. 1. To calculate the threshing efficiency and percentage of grain damage involved in threshing of each type of threshing cylinder fitted with cross flow portable paddy thresher. From the study suitable rasp bar cylinder (cast iron or nylon) was identified.

Development of a Threshing Cylinder

The threshing cylinder of 300 mm diameter and 300 mm length having four rasp bars on the periphery supported by a shaft fixed to the main frame of the thresher with the help of bearings. One end of the shaft is fitted with a stepped V-pulley to take power from the engine with the help of V-belts, to throw the threshed materials at the outlet.

Cast iron rasp bar threshing cylinder

Four commercially available rasp bars of 300 × 40 × 25 mm were fitted on the threshing drum 255 mm diameter, maintaining outer diameter as 300 mm with necessary wooden piece for proper sitting between the rasp bar and cylinder. Weight of each rasp bar is 2 kg (Fig. 2).

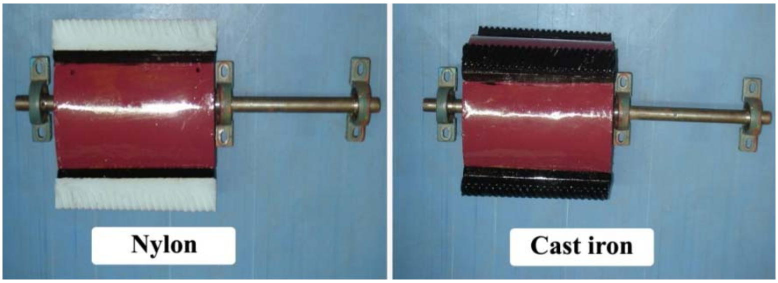

Figure 1. Comparison of threshing cylinders

Figure 2. Comparison of nylon and cast iron rasp bars

Nylon rasp bar threshing cylinder

Four commercially available rasp bars of 300 × 40 × 25 mm were fitted on the threshing drum 255 mm diameter, maintaining outer diameter as 300 mm with necessary wooden piece for proper sitting between the rasp bar and cylinder. Weight of the each rasp bar is 0.250 kg (Fig. 2). The rasp bar cylinder was developed and fitted with the portable paddy thresher (Overall size of 1500 × 900 × 1140 mm) and trial was taken up.

Experimental procedure

The thresher fitted with cast iron rasp bar cylinder surface was set to run at a fixed speed and concave clearance [7, 8]. The portable paddy thresher was run by electric motor for conducting trials (Fig. 3). A quantity of 3.4 kg of paddy panicles at a moisture content of 19.50% (d.b) was fed uniformly in to the thresher during a period of 60 seconds so as to get a feed rate of 200 $kg \cdot h^{-1}$. The grains collected at different outlet were weighed and the readings were recorded. All the readings from 3 replications were recorded. The experiment was repeated for the feed rate of 400 $kg \cdot h^{-1}$ and 600 $kg \cdot h^{-1}$. The cylinder speed varied from 11.7 to 16.5 $m \cdot s^{-1}$ with variable speed motor. Similarly, the concave clearance was changed to other levels and the observations were recorded for the three feed rates. Similarly for the other moisture levels of 16.50 and 13.50%, the above procedure was repeated and the observations were recorded and tabulated. This procedure was followed by nylon rasp bar threshing cylinder. An experiment with Factorial Completely Randomized Design was laid out. The factors considered and their levels are in Tab. 1. IRRISTAT was used to analyze the data. The treatment which gave good threshing efficiency with least grain damage was selected as the best.

Figure 3. Experimental study

Table 1. Design layout of FCRD experiment

Crop	Cylinder surface	Factors				Affected response variables
		Feed rate [kg·h^{-1}]	Cylinder speed [m·s^{-1}]	Concave clearance [mm]	Moisture content [%]	
Paddy	1. Cast iron rasp bar 2. Nylon rasp bar	200	11.7	15	13.5	Threshing efficiency and grain damage
		400	14.1	20	16.5	
		600	16.5	25	19.5	

No. of treatments: 3 × 3 × 3 × 3 = 81

RESULTS AND DISCUSSION

Effect of cylinder speed on threshing efficiency

From Tab. 2, it is seen that the increase in cylinder speed at each concave clearance had significant effect (Significant at 1 % level) on threshing efficiency, increasing the threshing efficiency from 98.489% to 98.726%. A maximum threshing efficiency of 98.889% could be achieved at a cylinder speed of 16.5 m s-1 with 20 mm concave clearance. Whereas it was 98.263% at a cylinder speed of 11.7 m s-1 with 25 mm concave clearance.

Table 2. Interaction effect of S × C factor means of threshing efficiency [%]

Concave clearance [mm]	Cylinder speed [m·s^{-1}]			
	11.7	14.1	16.5	C-Mean
15	98.644	98.762	98.850	98.752
20	98.561	98.654	98.889	98.701
25	98.263	98.363	98.439	98.355
S-Mean	98.489	98.593	98.726	98.603

Effect of moisture content on threshing efficiency

From Tab. 3, it is obvious that that the increase in moisture content from 13.5% to 19.5% and results in decrease in the threshing efficiency from 99.596% to 97.605%. The data are conformity with [9]. A maximum threshing efficiency of 99.677% could be achieved at a moisture content of 13.5% with 200 $kg \cdot h^{-1}$ feed rate. Whereas it was 97.532% at moisture content of 19.5% with 600 $kg \cdot h^{-1}$ feed rate.

Combined effect of cylinder speed, concave clearance and feed rate on threshing efficiency

Tab. 4 shows the combined effect of cylinder speed, concave clearance and feed rate. Increase in cylinder speed and increase in feed rate at each concave clearance had significant effect (at 1% level) on threshing efficiency varying the mean threshing efficiency from 98.258% to 98.851%. The maximum threshing efficiency of 98.961% could be achieved at a cylinder speed of 16.5 $m \cdot s^{-1}$ with a feed rate 600 $kg \cdot h^{-1}$ and concave clearance 20 mm. The minimum threshing efficiency was 98.161% at a cylinder speed of 11.7 $m \cdot s^{-1}$ with feed rate of 600 $kg \cdot h^{-1}$ and concave clearance of 25 mm. The data are in conformity with the results of Singh *et al.* (2003) [10].

Table 3. Effect of moisture content on threshing efficiency [%] at different feed rate

Grain moisture [%]	*Feed rate [$kg \cdot h^{-1}$]*			
	200	*400*	*600*	*M-Mean*
13.5	*99.677*	*99.591*	*99.521*	*99.596*
16.5	*98.695*	*98.597*	*98.525*	*98.605*
19.5	*97.679*	*97.605*	*97.532*	*97.605*
F-Mean	*98.684*	*98.597*	*98.526*	*98.602*

Performance evaluation of nylon rasp bar threshing cylinder for threshing efficiency

The effect of cylinder speed, concave clearance, feed rate and grain moisture on threshing efficiency was shown in Tab. 5 Cylinder speed (*S*), concave clearance (*C*), feed rate (*F*) and grain moisture (*M*) were individually influencing on threshing efficiency at 1.00% level. The interaction effect of *S x C, S x F, S x M, C x M, S x C x F, S x C x M, C x F x M* and *S x C x F x M* were influencing on threshing efficiency at 1.00% level. The interaction effects *F x M* was not significant. There was an increase in cylinder speed commensurate with increase in threshing efficiency at each concave clearance had significant effect on threshing efficiency, Increase in moisture content at each feed rate had significant effect on threshing efficiency, decreasing the threshing efficiency.

Comparative performance of threshing cylinders for threshing efficiency

In using a cast iron rasp bar threshing cylinder, it was observed that a higher threshing efficiency of 99.954% with combination effect of 16.5 $m \cdot s^{-1}$ cylinder speed, 15 mm concave clearance, 200 $kg \cdot h^{-1}$ feed rate and 13.5% moisture content. It was followed by threshing efficiency of 99.951% obtained from the combination of 16.5 $m \cdot s^{-1}$ cylinder speed; 20 mm concave clearance, 600 $kg \cdot h^{-1}$ feed rate and 13.5% grain moisture.

Table 4. Interaction effects of S × C × F factor means on threshing efficiency [%]

Feed rate [kg·h^{-1}]	Cylinder speed [m·s^{-1}] 11.7	14.1	16.5	F-Mean
C = 15 mm				
200	98.740	98.857	98.957	98.851
400	98.645	98.769	98.829	98.748
600	98.546	98.659	98.763	98.656
C = 20 mm				
200	98.643	98.749	98.848	98.747
400	98.570	98.651	98.859	98.693
600	98.471	98.563	98.961	98.665
C =25 mm				
200	98.355	98.467	98.541	98.455
400	98.273	98.347	98.438	98.353
600	98.161	98.274	98.337	98.258
S-Mean	98.489	98.593	98.726	98.603

Table 5. Interaction effects of S×C×F×M factor means on threshing efficiency [%]

Concave clearance [mm]	Feed rate [kg·h^{-1}]									C-Mean
	F_1=200			F_2=400			F_3=600			
	Cylinder speed [m·s^{-1}]			Cylinder speed [m·s^{-1}]			Cylinder speed [m·s^{-1}]			
	S_1 11.7	S_2 14.1	S_3 16.5	S_1 11.7	S_2 14.1	S_3 16.5	S_1 11.7	S_2 14.1	S_3 16.5	
M_1= 13.5%										
15	99.70	99.83	99.98	99.53	99.77	99.83	99.38	99.63	99.73	99.71
20	99.58	99.73	99.83	99.47	99.63	99.87	99.34	99.57	99.93	99.66
25	99.12	99.47	99.53	99.22	99.33	99.47	99.12	99.28	99.33	99.32
M_2= 16.5%										
15	98.73	98.87	98.97	98.63	98.78	98.83	98.47	98.68	98.77	98.75
20	98.53	98.78	98.83	98.53	98.51	98.87	98.37	98.66	98.97	98.67
25	98.28	98.46	98.52	98.23	98.34	98.43	98.07	98.27	98.34	98.33
M_3= 19.5%										
15	97.63	97.74	97.83	97.54	97.67	97.74	97.48	97.53	97.63	97.64
20	97.53	97.64	97.78	97.49	97.57	97.77	97.38	97.44	97.88	97.61
25	97.23	97.35	97.43	97.17	97.28	97.38	97.13	97.18	97.28	97.27
S-Mean	98.48	98.65	98.74	98.42	98.54	98.69	98.30	98.47	98.65	-

In using a nylon rasp bar threshing cylinder, it was seen that higher threshing efficiency of 99.978% with combination effect of 16.5 m·s^{-1} cylinder speed, 15 mm concave clearance, 200 kg·h^{-1} feed rate and 13.5% moisture content, which is higher than the cast iron rasp bar threshing cylinder with same combination effect. It was followed by threshing efficiency of 99.926% that was obtained from the combination of 16.5 m·s^{-1} cylinder speed; 20 mm concave clearance, 600 kg·h^{-1} feed rate and 13.5% grain moisture, which is lower than the cast iron rasp bar threshing cylinder with same combination effect. The data are in conformity with the results in [11]. The comparative performance of the cast iron rasp bar gave higher mean threshing efficiency of 98.603% than the mean threshing efficiency of 98.551% of nylon rasp bar threshing cylinder.

Effect of cylinder speed on grain damage at different concave clearances

From Tab. 6a it is observed that the increase in cylinder speed at each concave clearance had significant effect (at 1 % level) on grain damage. The minimum grain damage was observed as 1.857 at a cylinder speed of 11.7 $m \cdot s^{-1}$ with 25 mm concave clearance. A maximum grain damage of 2.395% was observed at a cylinder speed of 16.5 $m \cdot s^{-1}$ with 15 mm concave clearance.

Table 6. Interaction effect of S × C factor means on grain damage [%]

Concave clearance [mm]	a. Cast iron rasp bar threshing cylinder				b. Nylon rasp bar threshing cylinder			
	Cylinder speed [$m \cdot s^{-1}$]							
	11.7	14.1	16.5	C-Mean	11.7	14.1	16.5	C-Mean
15	2.302	2.347	2.395	2.348	1.316	1.379	1.444	1.380
20	2.174	2.230	2.285	2.230	1.269	1.317	1.386	1.324
25	1.857	2.111	2.156	2.042	1.214	1.277	1.318	1.270
S-Mean	2.111	2.230	2.279	2.206	1.266	1.324	1.383	1.325

From Tab. 6b it is observed that the increase in cylinder speed at each concave clearance had significant effect (at 1 % level) on grain damage, increasing the mean grain damage from 1.266% to 1.383%. The minimum grain damage was observed as 1.214 at a cylinder speed of 11.7 $m \cdot s^{-1}$ with 25 mm concave clearance. A maximum grain damage of 1.444% was observed at a cylinder speed of 16.5 $m \cdot s^{-1}$ with 15 mm concave clearance. The nylon rasp bar threshing cylinder was given minimum mean grain damage (1.325%) than the cast iron rasp bar threshing cylinder (2.206%).

Effect of moisture content on grain damage at different feed rate

From Tab. 7a it is inferred that the increase in feed rate at each grain moisture had significant effect (at 1 % level) on grain damage varying from 2.338% to 2.077%. The minimum grain damage observed was 1.469% at a feed rate of 600 $kg \cdot h^{-1}$ at 19.5% moisture content. The maximum damage was obtained as 2.975% at 200 $kg \cdot h^{-1}$ feed rate at 13.5% moisture for cast iron rasp bar threshing cylinder.

From Tab. 7b it is inferred that the increase in feed rate at each grain moisture had significant effect (at 1 % level) on grain damage varying from 1.465% to 1.176%. The minimum grain damage observed was 0.580% at a feed rate of 600 $kg \cdot h^{-1}$ at 19.5% moisture content. The maximum damage was obtained as 2.134% at 200 $kg \cdot h^{-1}$ feed rate at 13.5% moisture level for nylon rasp bar threshing cylinder. A nylon rasp bar threshing cylinder was given the minimum grain damage of 1.325% than the cast iron rasp bar threshing cylinder of 2.206%.

Combined effect of cylinder speed, concave clearance and moisture content on grain damage

Tab. 8 shows the combined effect of cylinder speed, concave clearance and moisture content. It is seen that the increase in cylinder speed and increase in moisture at each concave clearance had significant (at 1 % level) effect on grain damage. Tab. 8a shows that the mean grain damage varying from 1.266% to 2.953%. A minimum grain damage of 1.216% could be achieved at cylinder speed of 11.7 m·s^{-1} with 19.5% grain moisture at 25 mm concave clearance. A maximum grain damage of 2.996% could be achieved at a cylinder speed of 16.5 m·s^{-1} with 13.5% gain moisture and 15 mm concave clearance for cast iron rasp bar threshing cylinder.

Table 7. Interaction effect of F × M factor means on grain damage [%]

Grain moisture [%]	a. Cast iron rasp bar threshing cylinder				b. Nylon rasp bar threshing cylinder			
	Feed rate [kg·h^{-1}]							
	200	400	600	M-Mean	200	400	600	M-Mean
13.5	2.975	2.820	2.719	2.839	2.134	1.930	1.674	1.913
16.5	2.470	2.266	2.044	2.260	1.474	1.373	1.273	1.373
19.5	1.571	1.525	1.469	1.522	0.785	0.697	0.580	0.688
F-Mean	2.338	2.204	2.077	2.206	1.465	1.333	1.176	1.325

Table 8: Interaction effect of S×C×M factor means on threshing grain damage [%]

Grain moisture [%]	a. Cast iron rasp bar threshing cylinder				b. Nylon rasps bar threshing cylinder			
	Cylinder speed [m·s^{-1}]			M-Mean	Cylinder speed [m·s^{-1}]			M-Mean
	11.7	14.1	16.5		11.7	14.1	16.5	
C= 15 mm								
13.5	2.914	2.949	2.996	2.953	1.910	1.955	2.023	1.963
16.5	2.268	2.316	2.369	2.318	1.367	1.426	1.471	1.421
19.5	1.723	1.775	1.820	1.773	0.671	0.756	0.839	0.755
C= 20 mm								
13.5	2.846	2.902	2.951	2.900	1.850	1.914	1.956	1.907
16.5	2.203	2.263	2.326	2.264	1.329	1.369	1.432	1.377
19.5	1.473	1.526	1.578	1.526	0.626	0.667	0.770	0.688
C=25 mm								
13.5	2.215	2.8669	2.900	2.661	1.816	1.864	1.926	1.869
16.5	2.141	2.2020	2.251	2.198	1.268	1.328	1.370	1.322
19.5	1.216	1.2666	1.317	1.266	0.559	0.640	0.660	0.619
S-Mean	2.111	2.2297	2.279	2.206	1.266	1.324	1.383	1.325

Tab. 8b shows that the mean grain damage varying from 0.619% to 1.963%. A minimum grain damage of 0.559% could be achieved at cylinder speed of 11.7 m·s^{-1} with 19.5% grain moisture at 25 mm concave clearance. A maximum grain damage of 2.023% could be achieved at a cylinder speed of 16.5 m·s^{-1} with 13.5% gain moisture and 15 mm concave clearance. The minimum mean grain damage of 1.325% was observed for nylon rasp bar threshing cylinder than the cast iron rasp bar threshing cylinder of 2.206%.

Selection of best combination for minimum grain damage

The grain damage was minimum in case of the cast iron rasp bar threshing cylinder of 1.158% at grain moisture of 19.5% with 25 mm concave clearance, 11.7 m·s^{-1} cylinder speed and 600 kg·h^{-1} feed rate. The grain damage was minimum in case of the nylon rasp bar threshing cylinder of 0.475% at grain moisture of 19.5% with 25 mm concave clearance, 11.7 m·s^{-1} cylinder speed and 600 kg·h^{-1} feed rate. The minimum mean grain damage of 1.325% for nylon rasp bar threshing cylinder, which is lower than the cast iron rasp bar threshing cylinder of 2.206% for all combinations effects. The nylon rasp bar was best for all combination effects for getting minimum percentage of grain damage.

Selection of best combination of factors

The test results were statistically analyzed for achieving maximum threshing efficiency and minimum grain damage. Comparing the overall performance, the 20 mm concave clearance, 16.5 $m \cdot s^{-1}$ cylinder speed, 13.5% moisture content and at a feed rate of 600 $kg \cdot h^{-1}$ combination was selected as the best combination of factor at which, the threshing efficiency was 99.95% and 99.93% respectively for cast iron rasp bar and nylon rasp bar threshing cylinder. The corresponding values of grain damage were 2.760% and 1.730% respectively.

CONCLUSION

In this study cast iron rasp bar and nylon rasp bar threshing cylinders were developed for paddy threshing and compared. From the results, it was observed that there were no significant differences in threshing efficiency among cast iron and nylon rasp bar threshing cylinders. As far as grain damage is concerned, the nylon rasp bar threshing cylinder recorded minimum grain damage of 1.73% where as cast iron threshing cylinder recorded 2.76%. From these results it was very clear that when using nylon rasp bar threshing cylinder 62% of paddy grains were saved from the damage while threshing and it can be recommended for paddy threshing.

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RAZVOJ I KOMPARATIVNO ISPITIVANJE BUBNJEVA ZA VRŠIDBU RIŽE SA GVOZDENIM I NAJLONSKIM LETVAMA

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Sažetak: Dve vrste vršidbenih bubnjeva, sa gvozdenim i najlonskim letvama, su razvijene i ugrađene u prenosivu vršalicu za pirinač. Kod svakog bubnja su ispitivani efikasnost vršidbe i oštećenje zrna pri različitim vrednostima: zazora (15, 20 i 25 mm), periferne brzine bubnja (11.7, 14.1 i 16.5 $m \cdot s^{-1}$), vlage zrna (13.5% , 16.5% i 19.5%) i protoka mase (200, 400 i 600 $kg \cdot h^{-1}$). Poredeći maksimalnu efikasnost vršidbe, minimum oštećenja zrna u različitim kombinacijama je postignut sa zazorom od 20 mm, perifernom brzinom bubnja od 16.5 $m \cdot s^{-1}$, vlažnošću zrna od 13,5 % i protokom mase od 600 $kg \cdot h^{-1}$. Oštećenje zrna u ovoj kombinaciji je bilo 2,76% i 1,73% redom, za gvozdene i najlonske letve. Efikasnost vršidbe u ovoj kombinaciji je bila 99,95% i 99,93% redom, za gvozdene i najlonske letve.

Ključne reči*: vršidba riže, najlonska letva, gvozdena letva, oštećenje zrna, efikasnost vršidbe.*

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APPLICATION OF COOLING IN POSTHARVEST HANDLING OF GRAIN

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***Abstract*:** The present paper addresses the issue of postharvest handling of grain with focus on storage, when cooling is used in order to maintain the quality of the processed product and the required storage period. The paper presents the results of the control measurements at postharvest equipment, their evaluation and comparison. The measurements were performed manually by the means of the measuring device Dickey - John type GAC 2100. Results of the measurements of temperature and moisture content of grain provide basis for decisions upon possible extension of the storage period, alternatively upon further processing of grain. The paper also describes methods of maintaining the required parameters during grain storage, such as cold preservation. This section includes description and operating principle of the device Granifrigor; the recommended storage periods of different types of crops, depending on moisture content and temperature of cooling of grain. Moreover, principles of grain storage are described with respect to division according to moisture content.

Key words: *grain, control measurement, cold preservation, agriculture*

INTRODUCTION

Grain is one of the most important staple foods. It is planted and harvested with great care. According to the Food and Agriculture Organisation of the United Nations

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(FAO), more than 20% of the world's harvested grain is spoiled every year. The major part of this loss is caused by insects and mould activity.

Postharvest handling of grain is essential for reduction of moisture content to proper storage value of 13-14%. In storage conditions incompatible with the prescribed moisture content occurs deterioration of grain, for example mashing, moulds etc. Determination of mass of dry matter for calculation of moisture content dry basis and moisture content wet basis should be carried out in accordance with the standards for particular materials. Various devices operating with different electrical properties of tested materials are used to measure moisture content of agricultural materials. Identification of moisture content follows the procedure established by the producer.

Since grain is an organism, metabolic process of respiration is present. Intensity of respiration is influenced particularly by grain moisture content, temperature and amount of surrounding air. Grain constantly respires and under certain conditions it "comes to life". Therefore it is necessary to monitor several parameters, such as temperature, moisture content, changes of colour, odour development, pest infestation etc. When the moisture content increases, water from the process of respiration accumulates and supports further metabolic processes. Generated heat contributes to even more intense respiration and may eventually damage sensory and physiological properties of grain or spontaneous combustion may occur [1].

The paper is focused on the issue of maintaining the required parameters during grain storage. This practice is of great importance in terms of the period and quality of grain storage depending on grain moisture content [2].

MATERIAL AND METHODS

Water is fundamental to all life processes of organisms. It exists on their surface, in capillaries and inside the cells of their particular components as well. Reduction of water content is vital for long-term preservation of the material, because it generates conditions which inhibit biological activity. Moisture is the carrier of metabolism, i.e. chemical response of organisms to their environments. At the same time it is necessary to consider maintaining of utility of grain. More specifically, it means maintaining of germination of seed corn, maintaining of certain kinds of proteins, carbohydrates, fats, vitamins and ferments, which determine quality of the particular material or enhance properties relevant for further processing as food, forage or in the industry. Therefore knowledge and precise determination of moisture content of the material is of considerable importance [3].

Determination of mass of dry matter (M_{MS}) for calculation of moisture content dry basis and moisture content wet basis should follow the standards for the materials in question. If such standard does not exist yet, the sample of the material is dried in laboratory dryer at temperature exceeding the atmospheric boiling point of removed moisture (e.g. water at 105°C). Mass loss of the sample is examined in half hour intervals. Mass of dry matter is identified as mass of the sample which remains constant during further drying.

Moisture content of agricultural materials can be measured by various devices operating on the principle of different electrical properties of tested materials. Measurements follow the procedure established by the producer. When determining moisture content of crops outside the measuring range of the device or when using difficult-to-grind samples, it is possible to adhere to the following instructions: the amount of test sample with higher moisture content is mixed with a sample of the same weight with known lower moisture content. The mixture is thoroughly stirred and used for measurements. Moisture content of the sample is calculated according to the relation [4]:

$$w = 2w_1 - w_2 \tag{1}$$

where:
w [%] - moisture content of the sample,
w_1 [%] - measured moisture content of the mixture,
w_2 [%] - moisture of the sample with known lower moisture.

Moisture content of the dried materials is presented in accordance with the valid standard as moisture content dry basis and moisture content wet basis [5,6]:

$$u = \frac{M_V}{M_{MS}} = \frac{M_M - M_{MS}}{M_{MS}} \tag{2}$$

$$w = \frac{M_V}{M_M}100 = \frac{M_M - M_{MS}}{M_M}100 \tag{3}$$

where:
u [kg.kg^{-1}] - moisture content dry basis,
w [%] - moisture content dry basis,
M_V [kg] - mass of moisture,
M_M [kg] - mass of moist material,
M_{MS}[kg] - mass of dry matter.

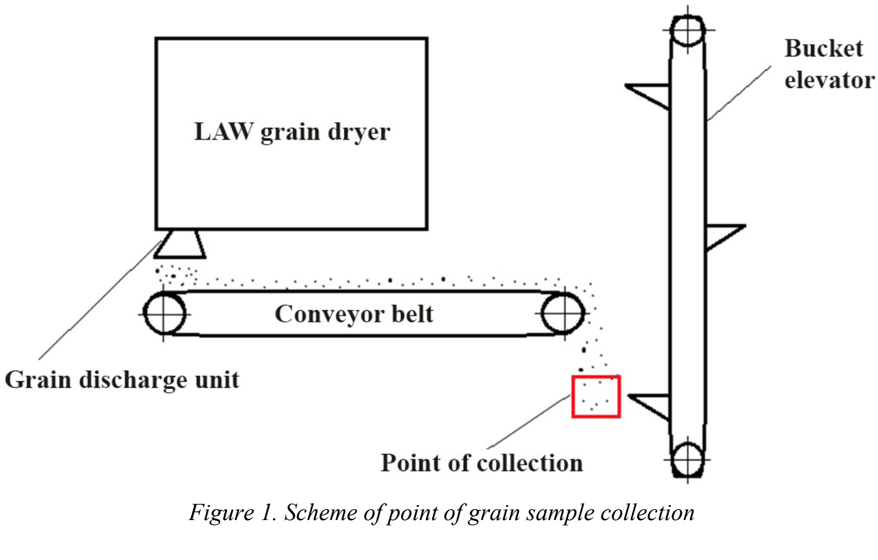

Figure 1. Scheme of point of grain sample collection

Control measurement at postharvest machinery is performed by the means of manual device Dickey - John type GAC 2100 for measuring of grain moisture content. The results obtained from the same hygrometer may be influenced by different conditions during cultivation, maturation and also by moisture content, temperature, harvest, transport and dirt content, especially regarding grains with high moisture content. Methods of calibration checking of grain hygrometers are established by the Slovak Technical Standard STN ISO 7700-1 [7].

AC 2100 is a reliable device designed for immediate determination of moisture content, temperature and bulk density for 64 different crops [3].

It operates on the following principle of analysis:

- filling of the chamber with grain,
- automatic weighing,
- automatic temperature correction,
- automatic bulk density compensation,
- emptying of the chamber.

Main parameters:

- measured quantities: moisture content, temperature and bulk density,
- moisture range: 5 to 45% (depending on calibration curve of the crop),
- crop temperature: 0 ° - 50 °C,
- temperature difference: 20 °C (room to grain sample),
- sample size: approximately 250 grains

Cold preservation by means of cooling device Granifrigor KK 220

The advantage of cold preservation is particularly risk-free storage without quality loss even in big warehouses. Low temperatures of grain provide reliable protection against insect infestation and their reproduction. As a result, potential costs of expensive chemical treatment and gassing are avoided [8].

Cool, dust-proof spot protected from the weather is suitable for installation. The distribution box should be during warm summer days located in the shadowy side of the building.

Parameters:

- cooling performance in 24 hours (220- 350 $t \cdot day^{-1}$)
- chilled air fan: volume flow at back pressure 1000 Pa (5700 $m^3 \cdot h^{-1}$)
2000 Pa (4900 $m^3 \cdot h^{-1}$)
3000 Pa (3500 $m^3 \cdot h^{-1}$)
- refrigerating capacity compressor (31,3 kW)
- average output (26,0 kW)
- electrical connection (63 A)
- diameter of connection cold air hose (300 mm)
- condensation water runoff average (16 $l \cdot h^{-1}$)
- weight (850 kg)

The fan of the Granifrigor grain cooler draws in the ambient air. This air is simultaneously cooled by an air conditioner (evaporator) to the desired temperature and dehumidified while moisture is being removed. The Hygrotherm unit then warms the cold air again, thereby lowering relative humidity. The Hygrotherm unit uses energy from the cooling circuit for heating. Therefore additional energy costs are effectively prevented. Cooled and dried air is fed through the air distribution of the warehouse and is forced through the grain. This system is suitable for use both in warehouses and tower silos. Eventually, the air is released outside through the exhaust vents while it extracts heat and moisture absorbed from the grain [3].

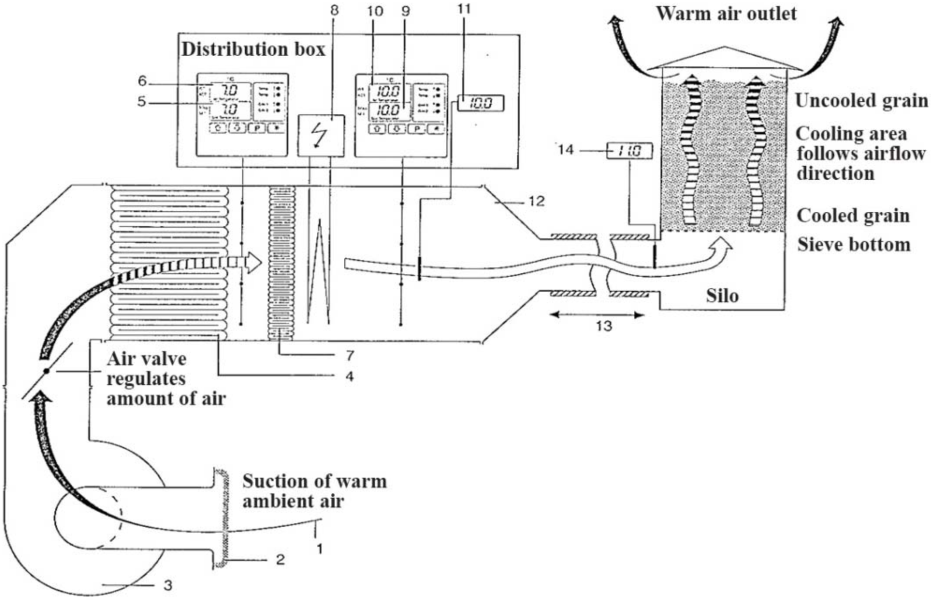

Figure 2. Scheme of air treatment by the device Granifrigor

1- air inlet, 2- dust filter, 3- centrifugal cool air fan, 4- cooling system, 5- controller of cooling air temperature, 6 - indicator of temperature after the cooling system, 7- Hygrotherm unit (for warming and drying of cooling air), 8 - electric heating register, 9 - controller for further heating, 10 - temperature controller for outlet temperature, 11- temperature indicator for outlet temperature, 12- cold air outlet from Granifrigor, 13 - channel of cooling air into the silo; in this area occurs further heating of the cool air by heat transfer, 14- recommended thermometer for cooling air temperature at silo inlet.

Before interruption of cooling, it is important to observe the cooling temperature in order to avoid interaction of warm air with cooler grain once the cooling process is restarted. Regular temperature monitoring in warehouses is crucial for early detection of changes and prevention of damage from overheating.

Average temperature at which development of insects ceases is +15 °C or lower. Growth of microbes and moulds is significantly inhibited by cooling. Whereas growth of woodworm stops at 5 °C, fundamental factor in its life cycle is moisture. Grain infested by woodworm should be definitely more dried and repeatedly cooled.

Principles of grain storage:

- dry grain (moisture content 12 – 15%): warm parts which should be stored for more than 3 months are considerably cooled in order to avoid self-heating and insects. Areas infested with insects should be always cooled as quickly as possible to prevent their further spreading to other warehouses. Storage temperature: ca. 13 – 16 °C.
- grain with critical moisture content (15,5 – 17%) is no longer dried, only cooled. Storage temperature: ca. 10 – 11 °C.
- moist grain (moisture content up to 22%): cooled grain has long-term storability. Storage temperature: ca. 7 – 8 °C.
- moist grain (moisture content exceeding 25%): large amounts of grain should be partially dried in a dryer, reduction of moisture content may considerably extend the period safe from self-heating. On the other hand, small amounts (approximately corresponding to dryer performance in 24 hours) with very high moisture content- for example maize with moisture content of 30 – 40 % - may be preserved by cooling for several days. Storage temperature: ca. 5 – 6 °C [9].

RESULTS AND DISCUSSION

Control measurement of a grain sample at the postharvest machinery is carried out every hour. The grain sample is collected from a point which is located between a conveyor belt which extracts the material from the grain dryer and a bucket elevator which transports the material for storage or distribution. The weight of the test sample is at least 250 g.

The test sample is poured into the chamber of the measuring device. The device automatically weighs the test sample. The measurement is activated by pressing the appropriate button which enables determination of the particular type of the material. The obtained values of moisture content and temperature of the test sample are then shown on a display. These values are then noted down in the appropriate table „Dryer SBC- operating journal".

In discharge rate 0,6/50, 0,6 is duration of discharging and 50 is duration of the drying cycle.

Table 1. Measured values at the grain postharvest machinery

Date	*Time*	*Temperature [°C]*		*Product moisture content [%]*		*Discharge rate*	*Settings*
		Warm air	*Product*	*Initial*	*Final*		*Fuel nozzle*
4.12.2012	*9^{00}*	*129,1*	*57,4*	*24,7*	*13,8*	*0,6/50*	*130 °C*
	10^{00}	*128,3*	*56,8*	*24,3*	*13,7*	*0,6/50*	
	11^{00}	*129,1*	*55,8*	*24,7*	*14,0*	*0,6/52*	
	12^{00}	*129,5*	*56,6*	*25,9*	*13,9*	*0,6/50*	
	13^{00}	*129,1*	*55,6*	*31,8*	*14,0*	*0,6/52*	
	14^{00}	*128,1*	*57,3*	*31,0*	*13,8*	*0,6/51*	
	15^{00}	*129,1*	*56,9*	*26,0*	*13,6*	*0,6/51*	
	16^{00}	*127,8*	*56,4*	*24,8*	*14,2*	*0,6/51*	
	17^{00}	*128,1*	*56,2*	*22,8*	*13,9*	*0,6/52*	

If final moisture content does not reach the desired values which are essential for storage without unwanted difficulties, discharge rate may be modified by the following methods:

- increase of the temperature of warm air,
- extension of the drying cycle.

Tab. 2 indicates that the LAW dryer has considerably higher average difference between initial and final moisture content than the B1 – 15 dryer at drying of maize at lower performance when considering analogical amount of maize before drying. Similarly, consumption of both gas and electric energy of the LAW dryer is significantly lower than that of the B1 – 15 dryer.

Table 2. Results of drying for the particular years

Year	unit	2003	2004	2011	2012
		Dryer type			
		B1-15	B1-15	LAW	LAW
Maize before drying	[t]	9112	9029	12059	9483
Maize after drying	[t]	8645	8393	10549	85586
Days of operation	[d]	28	31	34	25
Hours of operation	[h]	346	471	694	517
Average operation	[$h \cdot day^{-1}$]	12,3	15,1	20,4	20,7
Gas consumption	[1000 m^3]	62	152	166	127
Electric energy consumption for drying	[1000 kWh]	30	41	45	34
Electric energy consumption for cleaning	[1000 kWh]	26	35	51	40
Average difference between initial and final moisture content	[%]	3,5	7,2	8,9	8,8
Average performance	[$t \cdot h^{-1}$]	25	17,8	15,2	16,6
Average performance	[$t \cdot h^{-1}$]	26,3	19,2	17,4	18,4
Gas consumption	[$m^3 \cdot t\%^{-1}$]	1,95	2,34	1,55	1,52
Electric energy consumption	[$kWh \cdot t\%^{-1}$]	0,94	0,63	0,42	0,41

Results of cold preservation

Sorption isotherms show the equilibrium state between grain moisture content and relative air humidity. Relative humidity of blown cooling air may be higher at cooling of more moist grain than at cooling of dry grain. At moisture content of 15% the grain is cooled to approximately the same temperature as the blown air. When considering very dry areas of grain (8 – 13%), the achievable temperature of grain is substantially higher than the temperature of blown air (3 – 6 °C).

Table 3. Storage period of seed grain and malting barley

Seed grain and malting barley		
Moisture content	Storage temperature	Approx. storage period
12,0 – 15,0%	9 – 12 °C	long-term storage
15,0 – 16,5%	8 – 10 °C	1 – 1,5 years
16,5 – 18,0%	5 – 7 °C	4 – 6 months
18,0 – 20,0%	5 °C	2 – 3 months
20,0 – 22,0%	5 °C	3 – 4 weeks

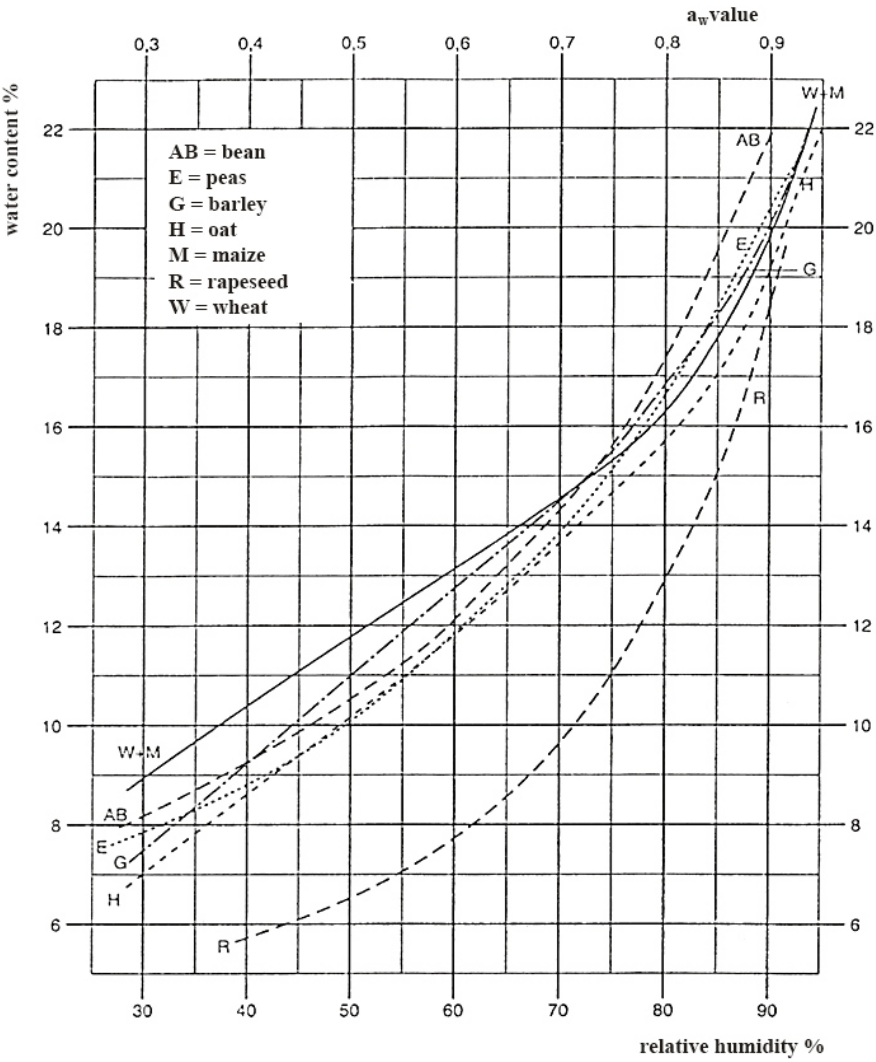

Figure 3. Sorption isotherm of different types of grain

Table 4. Storage period of edible wheat

Edible wheat		
Moisture content	*Storage temperature*	*Approx. storage period*
12,0 – 15,0%	*10 – 22 °C*	*long-term storage*
15,0 – 16,5%	*9 – 10 °C*	*long-term storage*
16,5 – 18,9%	*8 – 10 °C*	*5 – 10 months*
18,0 – 20,0%	*8 – 10 °C*	*2 – 7 months*
20,0 – 22,0%	*6 – 8 °C*	*4 – 16 weeks*

Table 5. Storage period of grain used as forage

Grain used as forage		
Moisture content	*Storage temperature*	*Approx. storage period*
12,0 – 15,0%	*10 – 22°C*	*long-term storage*
15,0 – 16,5%	*9 – 10°C*	*long-term storage*
16,5 – 18,9%	*8 – 10°C*	*6 – 13 months*
18,0 – 20,0%	*8 – 10°C*	*3 – 9 months*
20,0 – 22,0%	*6 - 8°C*	*5 – 20 weeks*

From the tables indicating storability of particular agricultural crops we can see that cooling by the means of the Granifrigor device may be an essential part of long-term storage of grain with various initial moisture contents. Cold preservation enables to maintain the properties of grain which are analogical to the quality prior to storage.

CONCLUSIONS

From the obtained results we may draw the following conclusions. The Granifrigor cooling device from the FrigorTech company is suitable for risk-free long-term storage of grain without quality loss. Other advantages of cooling of grain are protection against insect infestation and development of moulds and mycotoxines as well as minimisation of losses caused by grain respiration. From the economic point of view it is particularly convenient because expensive and unecological chemical treatment is prevented. In addition, costs of grain drying are lower and there is no need to restack the grain. Cooling may be carried out regardless of weather conditions while harvest freshness and germination of grain is maintained. The purchase of Granifrigor cooling device proved to be a long-term profitable investment.

The results of control measurement show that moisture content in every experiment ranged from 12 to 15%. These values are proper for long-term storage of grain. To summarise, the process of postharvest handling of grain in the Močenok farm may be considered as sophisticated in terms of expertise and technology due to modern equipment and qualified personnel.

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PRIMENA HLAĐENJA U POSTUPCIMA SA ZRNOM POSLE ŽETVE

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Sažetak**:** Ovaj rad se bavi postupcima sa zrnom posle žetve, sa naglaskom na skladištenje, kada se hlađenje koristi da bi se održao kvalitet prerađenog proizvoda i potrebni period skladištenja. U radu su prikazani rezultati kontrolnih merenja na opremi posle žetve, njihova evaluacija i poređenje. Merenja su obavljena ručno, mernim uređajem Dickey - John tipa GAC 2100. Rezultati merenja temperature i sadržaja vlage u zrnu daju osnove za odlučivanje o mogućem produženju perioda skladištenja ili daljim postupcima sa zrnom. U radu su takođe opisane metode održavanja potrebnih parametara tokom skladištenje žita, kao što je hladna zaštita. Ovaj deo uključuje opis i princip rada uređaja Granifrigor, preporučeno vreme za skladištenje različitih vrsta useva, u zavisnosti od sadržaja vlage i temperature hlađenja zrna. Štaviše, principi skladištenja žita su opisani u odnosu na podelu prema sadržaju vlage.

Ključne reči*: zrno, kontrolno merenje, hladna zaštita, poljoprivreda*

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QUALITY CHANGES OF SUGARCANE JUICE STORED IN DIFFERENT PACKAGING MATERIALS

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Abstract: Packaging materials selected were glass bottle, polyethylene (400 gauge) and polypropylene (350 gauge). Fresh sugarcane juice was pasteurized and processed at 80°C for 15 minutes and stored at 5°C and 30°C in the sterilized packaging materials. The biochemical and microbiological qualities analyzed were total sugars, reducing sugars, total soluble solids, titratable acidity, pH, bacteria, yeast and fungi. The fresh unpasteurized sugarcane juice without addition of preservative last for 4 days when stored at 5°C. Beyond that, the quality deteriorated, which was observed by the colour and flavour change. The juice stored at 30°C become spoilt within a day without any preservative. The quality loss due to biochemical and microbiological parameters were less in glass bottle followed by polyethylene and polypropylene with preservative. Microbial counts (bacteria, yeast, fungi) were increased, during storage of juice. The study revealed that apart from glass bottle, flexible polyethylene and polypropylene packaging materials could also be used to store sugarcane juices without much quality losses.

Key words: *Sugarcane juice, medicinal values, flexible packaging materials, preservative, storage temperature, biochemical qualities, microbiological qualities.*

INTRODUCTION

Sugarcane (*Saccharum officinarum* L.) is one of the most important commercial crops in the world. As per Sugarcane Statistical Report (2008), India is the second

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largest producer of sugarcane in the world next to Brazil. In India, Sugarcane is grown mainly for producing sweeteners such as sugar, jaggery and khandasari. The composition of sugarcane juice varies with variety, maturity, climatic and soil conditions and also the portion of the stalk from which it is extracted. Among the varieties grown in India, *CoP* 92226 variety is so popular because of its high juice yielding and sensory characteristics [1]. Sugarcane juice is a type of drink commonly found in Southeast Asia, South Asia and Latin America, and also in other countries where sugarcane is grown commercially. Sugarcane juice is very popular delicious drink both urban and rural areas in India but still it is rarely available commercially in packaged form. It is extracted by crushing sugarcane between roller crusher and consumed with (or) without ice. Sugarcane juice contains water (75 - 85 %), non-reducing sugars (sucrose, 10-21%), reducing sugars (glucose and fructose, 0.3 - 3%), organic substances (0.5-1), inorganic substances (0.2 - 0.6) and nitrogenous bodies (0.5-1) [2]. Sugarcane juice has many medicinal properties, often it is used as a remedy for jaundice in traditional medicine [3]. Sugarcane juice, is very useful in scanty urination, keeps the urinary flow clear and helps kidneys to perform their functions properly. Sugarcane juice of 100 ml provides 40 Kcal of energy, 10 mg of iron and 6 μg of carotene [4]. Due to its commercial importance, it is envisaged that sugarcane juice production can become a profitable business provided efforts to be made to preserve its fresh quality during storage. In general sugarcane juice is spoiled quickly due to presence of simple sugars [5]. The quality of cane juice is also affected by chemical (acid) and enzymatic inversion [6]. Sugarcane juice can be introduced as a delicious beverage by preventing the spoilage of juice with appropriate methods. Glass bottle is an excellent packaging material, which is impermeable to moisture and gases, odour resistance, good transparency and tamper resistance, is used for storing juice. Similarly, flexible packaging materials are also suitable for storing juices due to their low permeability characteristics, easy handling and high versatility. The selection of packaging materials to store sugarcane juice are mainly depends on the type of package, product, environment and product-package-environment relationship. Therefore the study was focused to find out the effects of different treatments on biochemical and microbiological qualities of sugarcane juice stored in different packaging materials.

MATERIALS AND METHODS

Sugarcanes variety of *CoP* 92226 (10 ± 11 months old) were harvested directly from the farmer's field. The harvested canes were immediately brought into the laboratory. Canes were cleaned, cut into pieces of uniform length, and washed in fresh water so as to remove the dust and dirt particles. Packaging materials used in the study were glass bottle, polyethylene (400 gauge) and polypropylene (350 gauge). The selected thickness of polyethylene and polypropylene packaging materials in the study was based on the optimization studies on heat withstanding capacity and quality loss due to biochemical and microbiological characteristics. Extraction of juice was done by three roller crusher. Juice was filtered through a four layer muslin cloth. The extracted juice was pasteurized at 80°C for 15 minutes and again filtered using muslin cloth. The pasteurized juices were cooled and added sodium benzoate preservative at a level of 100 and 125 ppm. The juices were filled in sterilized packaging materials viz., glass bottle, polyethylene (400 gauge) and polypropylene (350 gauge) at an volume of 250 ml and then processed (in bottle sterilization) at 80°C for 15 minutes. The different treatments used in the study were control (T_1), sugarcane juice with 100 ppm (parts per million) preservative at 30°C (T_2), sugarcane juice with 100 ppm preservative at 5°C (T_3), sugarcane juice with 125 ppm preservative at 30°C (T_4) and sugarcane juice with 125 ppm preservative at 5°C (T_5).

Biochemical analysis

The processed juices were stored at 5°C and 30°C. The biochemical qualities studied were, total sugars, reducing sugars, total soluble solids, titratable acidity, pH and sensory evaluation for colour and flavor [7]. The total soluble solids were measured using an ERMA hand refractometer. All the experiments were carried out in triplicates. Each values was a mean of three replications.

Microbiological analysis

The quality of sugarcane juice was based on the number and type of microorganism present, which can be assessed by serial dilution and plating method for the differential enumeration of bacteria, yeast and fungi. Determination of total microbial counts (bacteria, yeast and fungi) for juice was carried out at 0 h and every 24 h. One milliliter of juice from each storage temperature was taken into a test tube containing 9 ml of sterile water. The mixture was homogenized. This homogenate represented 10^{-1} dilution. From here, serial dilutions of 10^{-2}, 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} were prepared. The plates were then incubated at room temperature for 48 h for bacteria and four days for fungi and yeast [8]. Enumeration of bacteria was counted by nutrient agar media [9] with 10^{-6} dilutions. Yeast and fungi was counted by yeast extract agar media [10] with 10^{-4} dilutions and martin's rose bengal medium [11] with 10^{-3} dilutions. The results (number of colony forming units) were obtained after the incubation time using the following formula.

$$CFU_S = \frac{CFU_M \cdot DF}{S} \tag{1}$$

where:

CFU_S [g^{-1}]- number of colony forming units per gram of sample,
CFU_M [-] - mean number of colony forming units,
DF [-] - dilution factor,
S [g] - mass of the sample.

Sensory evaluation

Sensory evaluation of the stored juice was carried out by 20 panelists using a triangle test. The panelists rated the sample for colour, flavour, taste and acceptability using 9-point hedonic rating test method (1=dislike very much, 9=like very much) as recommended by [7]. The panelists were asked to identify the odd sample in terms of colour, flavour and taste compared to a freshly extracted juice.

Statistical analysis

Data were subjected to statistical measurement of analysis of variance (ANOVA) using Agres package.

RESULTS AND DISCUSSION

Total Sugars

Total sugars content decreased during storage. Total sugars content in the fresh sugarcane juice (T_1) was found to be 16.5 %. The decrease of sugar content of sugarcane juice was less (15.4%) in glass bottle for treatment T_5 followed by polyethylene and polypropylene packaging during storage (Tab. 1). This could be due to action of microorganism present in the juice, converted the total sugars into reducing sugars (glucose and fructose). All the treatments were found to be statistically highly significant ($p<0.01$). Similar results were reported by [12] and [13].

Table 1. Effect of treatments on total sugars (%) of sugarcane juice stored in different packaging materials

Days	Glass bottle				Polyethylene 400 gauge				Polypropylene 350 gauge			
	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5
10	15.2	16.0	15.5	16.2	14.8	15.9	15.3	16.1	14.6	15.7	15.2	15.9
20	14.8	15.7	15.3	16.0	14.6	15.6	15.0	15.9	14.5	15.3	14.9	15.7
30	14.7	15.5	15.1	15.9	14.5	15.4	14.8	15.8	14.3	15.0	14.6	15.6
40	14.5	15.2	14.9	15.7	14.3	15.1	14.7	15.6	14.2	14.9	14.5	15.4
50	14.0	15.0	14.6	15.6	13.9	14.9	14.5	15.5	13.8	14.7	14.3	15.1
60	13.8	14.9	14.5	15.4	13.6	14.8	14.4	15.3	13.5	14.6	14.2	15.0

**Values are mean of three replications*

Reducing Sugars

There was an increasing trend of reducing sugar content in the stored juice. This might be due to the fact that the hydrolysis of non-reducing sugars (sucrose) into reducing sugars (glucose and fructose) by the action of microorganism. Reducing sugars content in the fresh sugarcane juice was 0.45 % (T_1). The increase of reducing sugars was less (0.81%) in glass bottle for treatment T_5 followed by polyethylene and polypropylene during the storage (Tab. 2). The reason for increase of reducing sugars in polyethylene and polypropylene might be due to the variation in permeability of material for gas and water vapour. All the treatments were found to be highly significant with storage temperature, storage period and preservative. This result was in agreement with Pushpha singh *et al.* (2002) [14].

Table 2. Effect of treatments on reducing sugars (%) of sugarcane juice stored in different packaging materials

Days	Glass bottle				Polyethylene 400 gauge				Polypropylene 350 gauge			
	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5
10	0.49	0.47	0.48	0.47	0.51	0.48	0.50	0.48	0.52	0.51	0.51	0.50
20	0.57	0.50	0.53	0.49	0.62	0.52	0.56	0.52	0.65	0.56	0.59	0.53
30	0.64	0.58	0.59	0.53	0.68	0.62	0.64	0.58	0.71	0.64	0.68	0.60
40	0.82	0.65	0.76	0.60	0.86	0.74	0.82	0.64	0.92	0.75	0.86	0.65
50	1.10	0.80	0.94	0.72	1.18	0.86	1.10	0.80	1.24	0.91	1.20	0.87
60	1.25	0.92	0.98	0.81	1.32	1.12	1.24	0.87	1.38	1.23	1.27	0.98

**Values are mean of three replications*

Total Soluble Solids (TSS)

Total soluble solids decreased with increase in storage periods ($p<0.01$). This might be due to the action of microorganism present in the juice. The total soluble solids decrease was less in glass bottle (18.7^0 Brix) for treatment T_5 during storage (Tab. 3). This was in agreement with the findings of Ghorai and Khurdiya (1998) [15] in kinnow mandarin juice.

Table 3. Effect of treatments on total soluble solids (^{0}Brix) of sugarcane juice stored in different packaging materials

Days	Glass bottle				Polyethylene 400 gauge				Polypropylene 350 gauge			
	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5
10	18.0	18.9	18.5	19.0	17.8	18.50	18.9	19.0	17.7	18.4	18.8	18.9
20	18.0	18.8	18.4	18.9	17.6	18.30	18.8	18.9	17.6	18.3	18.6	18.8
30	17.8	18.6	18.3	18.8	17.5	18.30	18.6	18.8	17.4	18.2	18.6	18.6
40	17.7	18.5	18.2	18.8	17.5	18.20	18.4	18.6	17.3	18.2	18.5	18.6
50	17.7	18.5	18.2	18.7	17.3	18.15	18.4	18.6	17.3	18.0	18.3	18.4
60	17.5	18.2	18.1	18.7	17.2	18.10	18.5	18.6	17.1	18.0	18.2	18.3

**Values are mean of three replications*

Titratable Acidity

Titratable acidity of sugarcane juice increased during storage (Tab. 4). This might be due to the fact that acetic and lactic acid production taken place during storage. Sugarcane juice stored at 30°C recorded higher acidity range compared to those stored at 5°C. The increase of acidity was less in glass bottle (1.19 %) for treatment T_5 followed by polyethylene and polypropylene.

pH values

pH values of stored sugarcane juice were decreased at an equal rates during storage (Tab. 5). The reduction of pH during storage might be due to acetic acid production by the action of acetic acid bacteria. This result was in agreement with the study conducted by Chauhan *et al.* (1997) [12].

Table 4. Effect of treatments on titratable acidity (% citric acid) of sugarcane juice stored in different packaging materials

Days	Glass bottle				Polyethylene 400 gauge				Polypropylene 350 gauge			
	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5
10	0.95	0.89	0.91	0.87	0.98	0.90	0.94	0.91	1.10	0.93	0.98	0.93
20	1.15	0.94	0.97	0.90	1.21	0.95	0.99	0.92	1.26	0.98	1.10	0.95
30	1.20	1.0	1.10	0.98	1.25	1.14	1.15	1.10	1.32	1.20	1.17	1.19
40	1.23	1.14	1.17	1.10	1.28	1.20	1.20	1.15	1.38	1.25	1.25	1.22
50	1.28	1.18	1.20	1.14	1.32	1.24	1.24	1.18	1.43	1.28	1.28	1.25
60	1.35	1.22	1.25	1.19	1.39	1.28	1.28	1.20	1.45	1.32	1.32	1.28

**Values are mean of three replications*

Table 5. Effect of treatments on pH of sugarcane juice stored in different packaging materials

Days	Glass bottle				Polyethylene 400 gauge				Polypropylene 350 gauge			
	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5
10	4.90	4.98	4.95	5.0	4.80	4.90	4.90	4.90	4.65	4.80	4.70	4.85
20	4.52	4.65	4.60	4.70	4.30	4.50	4.40	4.60	4.40	4.55	4.45	4.63
30	4.21	4.42	4.40	4.63	4.20	4.30	4.25	4.42	4.0	4.25	4.15	4.20
40	4.05	4.25	4.25	4.50	3.90	4.10	4.05	4.15	3.85	4.05	4.00	4.10
50	3.90	4.10	4.05	4.43	3.50	3.95	3.90	4.00	3.73	3.86	3.80	3.95
60	3.75	4.05	4.0	4.21	3.43	3.85	3.75	3.90	3.65	3.72	3.70	3.80

**Values are mean of three replications*

Table 6. Effect of treatments on bacteria (10^6) population of sugarcane juice stored in different packaging materials

Days	Glass bottle				Polyethylene 400 gauge				Polypropylene 350 gauge			
	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5
10	1.65	1.50	1.65	1.48	1.72	1.63	1.69	1.57	1.85	1.73	1.79	1.70
20	2.05	1.97	2.00	1.65	2.14	2.02	2.04	1.98	2.23	2.12	2.14	1.94
30	2.25	2.13	2.16	1.96	2.63	2.23	2.51	2.15	2.87	2.39	2.41	2.03
40	2.87	2.54	2.74	2.14	2.94	2.76	2.79	2.53	3.15	2.94	3.03	2.49
50	2.96	2.73	2.89	2.42	3.14	2.96	2.98	2.79	3.69	3.25	3.27	3.08
60	3.18	2.99	3.11	2.57	3.58	3.10	3.16	3.04	3.96	3.49	3.67	3.25

**Values are mean of three replications*

Bacteria population

Bacteria population of the stored sugarcane juice increased during the storage (Tab. 6). The bacteria population in the fresh sugarcane juice was 4.5×10^6 Cfu's. The increase of bacteria population of stored juice was less in glass bottle for the storage period of 60 days at 125 ppm in 5°C. This might be due to low oxygen permeability characteristics of glass material. The bacteria population found to be highly significant with all the treatments. Similar results was found by Puspha singh *et al.* (2002) [14].

Yeast population

The yeast population also increased with increase in storage periods (Tab. 7). The yeast population in the fresh sugarcane juice was 5.2×10^4 Cfu's. The yeast population of stored sugarcane juice was highly significant ($p<0.01$) between storage temperature, preservative and storage periods. The low temperature storage had retarded the growth of micro-organisms.

Table 7. Effect of treatments on yeast (10^4) population of sugarcane juice stored in different packaging materials

Days	Glass bottle				Polyethylene 400 gauge				Polypropylene 350 gauge			
	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5
10	2.02	1.97	2.00	1.80	2.36	2.21	2.31	2.13	2.56	2.43	2.51	2.34
20	2.66	2.54	2.58	2.19	2.78	2.63	2.69	2.55	2.69	2.51	2.54	2.42
30	2.96	2.83	2.92	2.68	3.18	3.03	3.05	2.87	3.13	3.04	3.08	2.95
40	3.09	2.99	3.01	2.84	3.24	3.15	3.25	3.04	3.58	3.39	3.49	3.23
50	3.58	3.26	3.36	3.08	3.59	3.33	3.36	3.16	3.75	3.56	3.65	3.48
60	4.39	4.15	4.23	4.03	4.56	4.25	4.28	4.18	4.89	4.63	4.76	4.41

**Values are mean of three replications*

Table 8. Effect of treatments on fungi (10^3) population of sugarcane juice stored in different packaging materials

Days	Glass bottle				Polyethylene 400 gauge				Polypropylene 350 gauge			
	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5	T_2	T_3	T_4	T_5
10	1.0	1.00	1.00	1.00	1.20	1.13	1.15	1.10	1.25	1.20	1.20	1.20
20	1.6	1.20	1.20	1.00	1.34	1.23	1.25	1.15	1.39	1.26	1.26	1.23
30	2.2	2.00	2.05	2.00	2.50	2.31	2.41	2.33	2.63	2.49	2.55	2.45
40	2.8	2.30	2.43	2.20	2.96	2.77	2.83	2.69	3.05	2.84	2.87	2.74
50	3.1	2.80	2.85	2.73	3.24	3.03	3.05	2.87	3.31	3.10	3.17	3.05
60	3.4	3.16	3.18	3.00	3.65	3.38	3.44	3.19	3.69	3.43	3.53	3.29

**Values are mean of three replications*

Fungi population

Fungi count of the juice rises with time (Tab. 8). Presence of *Escherichia coli*, enterococci and other coliforms indicate fecal contamination of sugarcane juice, suggesting possible risk of infection involved while consuming juice such as sugarcane juice (Pelczar *et al.* 1993) [16]. Richa Karmakar *et al.* (2011) [17] reported that bacterial contamination may occur at different stages of juice processing such as by contamination of sugarcane, roller crusher, collecting vessel, ice, hands of the personnel and filter cloth.

The growth of fungi in juice stored at 30°C with preservative increased significantly ($p<0.05$) compared to juice stored at 5°C.

Sensory evaluation

Sugarcane juice stored in all the packaging materials were found to be statistically highly significant ($p<0.01$). From the mean values of statistical analysis, the glass bottle was found to be good for color, flavor and overall acceptability followed by polyethylene and polypropylene.

CONCLUSIONS

Fresh unpasteurized sugarcane juice last for 4 days when stored at 5°C without any preservative. Beyond that, the quality deteriorated, which was observed by the colour and flavour change. The juice stored at 30°C become spoilt within a day without any preservative. The reduction in sensory qualities of juice stored at 5°C with addition of preservative was significantly lower than the juice stored at 30°C. The loss of biochemical qualities and increase of microbiological counts were comparatively less in glass bottle followed by polyethylene and polypropylene with preservative. The cost of storing sugarcane juice in flexible packaging materials is relatively lower than glass bottle. Therefore it is economical and convenient to use flexible packaging materials like polyethylene and polypropylene for storing sugarcane juice without much quality reduction.

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PROMENE KVALITETA SOKA ŠEĆERNE TRSKE PRI PAKOVANJU U RAZLIČITE MATERIJALE

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Sažetak: Odabrani ambalažni materijali su bili staklena boca, polietilen (400) i polipropilen (350). Svež sok šećerne trske je pasterizovan, obrađen na 80°C tokom 15 minuta i upakovan na 5°C i 30°C u sterilne materijale za pakovanje. Biohemijske i mikrobiološke osobine koje su analizirane su: ukupni šećeri, redukujući šećeri, ukupne rastvorljive čvrste materije, titraciona kiselost, pH, bakterije, plesni i gljivice. Svež nepasterizovan sok šećerne trske bez dodatka konzervansa održao se 4 dana u skladištu na 5°C. Posle toga kvalitet se pogoršao, što je uočeno promenom boje i ukusa. Sok koji je čuvan na 30°C bez konzervansa pokvario se već prvog dana. Gubitak biohemijskog i mikrobiološkog kvaliteta bio je manji u staklenoj boci, a zatim u pakovanjima od polietilena i polipropilena sa konzervansom. Broj mikroorganizama (bakterije, plesni, gljivice) povećao se tokom skladištenja soka. Studija je pokazala da, pored staklene boce, fleksibilni polietilen i polipropilen takođe mogu da se koriste za pakovanje soka šećerne trske bez značajnog gubitaka kvaliteta.

Ključne reči: *sok šećerne trske, medicinske vrednosti, fleksibilni materijali za pakovanje, konzervans, temperature skladištenja, biohemijski kvalitet, mikrobiološki kvalitet.*

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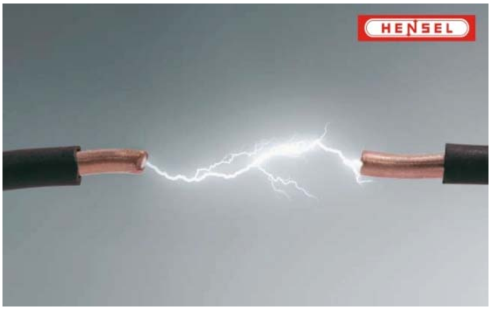
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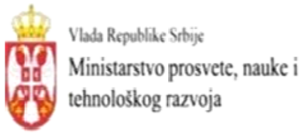
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