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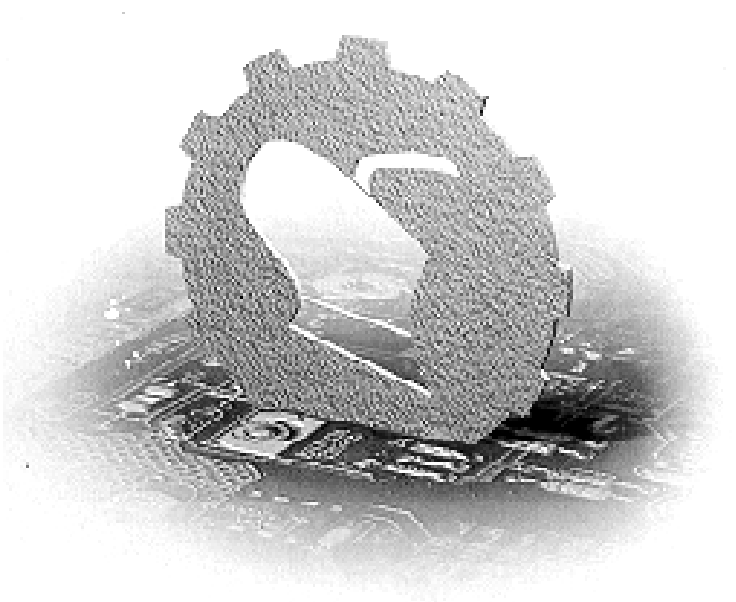

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ESTIMATE OF GHG EMISSIONS - THE GREENHOUSE GASES - A UNIVERSITY CAMPUS IN CONNECTION WITH THE ELECTRIC ENERGY CONSUMPTION

Fernando de Lima Caneppele[*1], Luís Roberto de Almeida Gabriel Filho[2], José Antonio Rabi[1], Breno Damião[1]

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Abstract: The impacts of the use of electricity to the environment, both by environmental impacts, as for energy policy issues or because it is finite resources is a topic of great importance today.

The purpose of this paper is to establish the amount of GHG emissions - Greenhouse Gas, from electricity consumption on the campus of the University of São Paulo in the city of Pirassununga.

This quantification is carried out from the results of electricity consumption and emission factor. Emissions related to energy consumption have been established and from this inventory, goals can be traced for future projects related to energy efficiency and consequent reduction of GHG emissions - Greenhouse Gases.

Key words*: electricity consumption, energy efficiency, CO_2 emission factor, GHG - greenhouse gases*

INTRODUCTION

This item is on energy efficiency, energy consumption, CO_2 emission factor and GHG emissions - Greenhouse Gases.

Energy efficiency and electricity consumption. Energy security, international competition and climate change are increasingly driving the development and implementation of government policies on energy efficiency (IEA, 2010). [1]

Combating waste of electricity is advantageous for everyone involved. The consumer wins, passing a compromise smaller portion of their costs, the electricity sector, postponing investments necessary to meet new customers, and society as a whole, because besides the saved resources, energy efficiency activities generate jobs through

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the service itself and the use of equipment, almost entirely manufactured in the country and contribute to the preservation and improvement of the environment avoiding the environmental damage inherent in the construction of hydroelectric plants or the operation of thermal power plants (ELETROBRÁS, 2005). [2]

To invest in energy efficiency measures, it is essential for companies to gather information from all the technological options available, the benefits and costs of each option and the impact these technologies will have on production processes (for example, interruption of process production) (IEA, 2011). [3]

CO_2 emission factors. The average CO_2 emission factors for electricity to be used in inventories have to estimate the amount of CO_2 associated with a particular generation of electricity. It averages the generation of emissions, taking into account all the plants that are generating energy and not only those who are working in the margin. In this regard, it should be used when the objective is to quantify emissions from electricity being generated at any given time. It serves therefore to inventories in general, corporate or other (ENERGY FORUM, 2014). [4]

The inventory of GHG - Greenhouse Gases - is a tool to quantify the emissions of an organization that are associated with climate change, within internationally recommended criteria. As inventory the organization can assess its impact in this context of climate change, allowing action strategies are mounted for mitigation and prioritization of effective action to reduce emissions.

GHG emissions - Greenhouse Gases. Of all the activities that generate GHG - Greenhouse Gas, the energy sector is the largest contributor to global warming, and issued in 2005, 64% of GHG emissions in the world (IEA, 2008). [5]

At a time that global warming and climate change are of concern in the world, improving energy efficiency is the most cost effective and quick solution to minimize environmental impacts caused by the use of energy and reduce carbon dioxide (CO_2) (PETROBRAS, 2008). [6]

In Brazil, the high share of renewable energy in the energy matrix, mainly hydroelectricity, alcohol use in transport and sugarcane bagasse and charcoal in the industry make carbon dioxide (CO_2) by Use of relatively small fossil fuels. This difference in matrix composition puts Brazil in a favorable position relative to the global average, particularly with respect to GHG emissions - Greenhouse Gases (MCTI, 2010).[7]

According to there are several ways of reducing emissions of greenhouse gases and the effects on global warming. Reduce deforestation, invest in reforestation and conservation of natural areas, encourage the use of non-conventional renewable energy (solar, wind, biomass and small hydroelectric plants), prefer to use biofuels (ethanol, biodiesel) fossil fuels (gasoline, diesel fuel), invest in reducing energy consumption and energy efficiency, reduce, reuse and recycle materials, invest in low-carbon technologies, improving public transport with low greenhouse gas emissions, they are some of the possibilities. And these measures can be established through national and international climate policies (WWF, 2009). [8]

Research related to carbon dioxide release (CO_2) and other greenhouse gases - Greenhouse gases to the atmosphere were described by [9,10,11,12,13,14,15].

GHG emissions - greenhouse gas-related electricity use are described by [16,17,18,19,20].

MATERIAL AND METHODS

The study was conducted on the campus of Faculty of Animal Science and Food Engineering - FZEA the University of São Paulo - USP, in the city of Pirassununga - Sao

Paulo - Brazil. This campus is the largest of 'Campi' the University of São Paulo in area and is in fact an experimental farm with a total area of 23,333,204.00 m2 with perimeter 26535.55 m; and 80594.00 m^2 of built area (USP, 2013). [21]

The data on energy consumption on campus were obtained from a database with information about the USP energy bills called ContaluzWeb system.

Data from the emission factors related to energy consumption were obtained from the MCTI - Ministry of Science, Technology and Innovation (2015) [22] and the calculation of emissions was conducted using the methodology described in the CO_2 emission factors according to methodological tool "Tool to calculate the emission factor for an electricity system, versions 1, 1.1, 2, 2.1.0 and 2.2.0" approved by the Executive Board of the CDM - Clean Development Mechanism ".

The document "Tool to calculate the emission factor for an electricity system" is currently at version 5.0 and maintains the methodology used in previous versions. [23]

RESULTS AND DISCUSSION

They present the results for the monitoring and analysis of campus electricity bills, monitoring and analysis of the emission factors associated with electricity consumption and inventory / quantification of GHG emissions - greenhouse gases related to electricity consumption.

Electricity Consumption. By ContaluzWeb system was checked the power of the campus consumption for the year 2014, as listed in Tab. 1.

Table 1. Electricity consumption on the university campus in 2014

Electricity Consumption (MWh)											
Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
340,4	*363,9*	*366,8*	*381,6*	*372,1*	*343,1*	*334,0*	*339,7*	*355,9*	*400,6*	*428,2*	*377,8*

CO_2 emission factor. The Ministry of Science, Technology and Innovation, organ of the Brazilian Government, releases the CO_2 emission factors for electricity generation in the SIN - National Interconnected System of Brazil from the base year 2006. This data is available on average annual, monthly, daily and hourly.

The average CO_2 emission factors for electricity to be used in inventories have to estimate the amount of CO_2 associated with a particular generation of electricity.

By MCTI (2015) [22], is listed in Tab. 2 CO_2 emission factor measured during the year 2014 in the SIN - National Interconnected System of Brazil.

Table 2. CO_2 emission factor in SIN - Brazil's National Interconnected System in 2014

CO_2 emission factor (tCO_2/MWh)											
Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
0,091	*0,117*	*0,124*	*0,131*	*0,142*	*0,144*	*0,146*	*0,158*	*0,143*	*0,141*	*0,151*	*0,137*

GHG emissions - Greenhouse Gases. According to MCTI (2015) [22], that all electricity consumers in the SIN - National Interconnected System - calculate their emissions by multiplying the energy consumed by this emission factor, the sum corresponds to emissions of CO_2 emissions. Tab. 3 lists the monthly CO_2 emissions in 2014 to the university campus.

Table 3. CO_2 emission in 2014

CO_2 emission (tCO_2)											
Jan.	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*
31,0	*42,5*	*45,4*	*50,0*	*52,9*	*49,4*	*48,9*	*53,6*	*50,9*	*56,6*	*64,8*	*51,7*

Chart 1 are the amounts of CO_2 (t CO_2) related to electric power consumption in 2014.

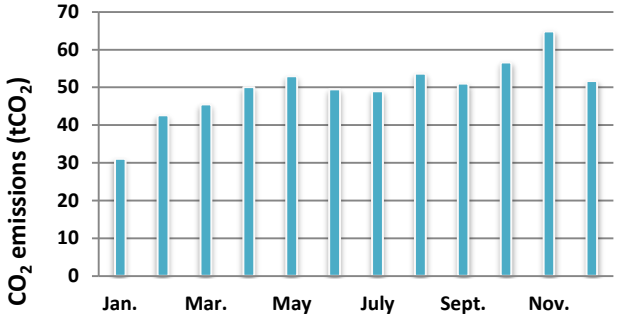

Figure 1. CO_2 emissions (tCO_2) related to electricity consumption in 2014

A trend of increasing CO_2 emissions was observed (t CO_2) every month in the year 2014. The monthly average emission was estimated at 49.8 (t CO_2) on the university campus related to the consumption of electricity. In the year 2014 it was issued a total of 598 (t CO_2).

CONCLUSIONS

CO_2 emissions related to the consumption of electricity on the campus of the University of São Paulo in the city of Pirassununga were quantified and this inventory is intended to set goals for future projects related to energy efficiency to reduce greenhouse gas emissions - Gases Greenhouse.

In times of global warming, the effects of the high standards of production and consumption lead to global society, companies and public institutions to reflect deeply on issues related to sustainability in different views, such as the environmental economic and social and researching new forms of energy development that are compatible with sustainable development.

It is intended with the data and results of this project show that when consuming electricity is issued a significant amount of GHG - Greenhouse Gases. One of the expected effects of the disclosure of this inventory in the community's awareness to change consumption habits and reduce electricity consumption.

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PROCENA GHG EMISIJA – GASOVA STAKLENE BAŠTE – UNIVERZITETSKOG KAMPUSA U ODNOSU NA POTROŠNJU ELEKTRIČNE ENERGIJE

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Sažetak: Uticaj električne enrgije na okolinu, kako zbog zaštite okoline, tako i zbog potrošnje energije iz neobnovljivih izvora je danas veoma važna tema.

Cilj ovog rada je da odredi količinu GHG emisija – gasa staklene bašte, iz potrošene električne energije u kampusu Univerziteta São Paulo u gradu Pirassununga.

Procena je izvedena iz rezultata potrošnje električne energije i faktora emisije. Procenjene emisije u odnosu napotrošnju energije mogu da posluže za buduće projekte iz oblasti energetske efikasnosti i smanjenja emisija – gasova staklene bašte.

Ključne reči*: potrošnje struje, energetska efikasnost, factor CO_2 emisije, GHG – gasovi staklene bašte*

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ZNAČAJ EFIKASNOG RAD ZAGREJAČA NA DIZEL MOTORIMA

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Sažetak: Zagrejač dizel motora, sa plamenim grejanjem, predstavlja sistem koji pospešuje startovanje dizel motora sa unutrašnjim sagorevanjem, posebno u hladnim vremenskim uslovima. U cilju iznalaženja mogućnosti za povećanje temperature usisnog vazduha dizel motora, usledilo je istraživanje nove konstrukcije gorionika zagrejača pomoću zadatog algoritma. Izvršena je adaptacija usisne grane dizel motora da_bi se posmatralo prostiranje plamena zagrejača i oceno kvalitet. Ova istraživanja su sprovedena pomoću već razvijene metodologija za laboratorijsko ispitivanje tehničko-funkcionalnih karakteristika zagrejača uz upotrebu savremenog sistema za merenje, akviziciju i monitoring procesa ispitivanja. Istraživanja su pokazala da je kraće vreme startovanja dizel motora pri upotrebi zagrejača sa gorionikom od šesnaest otvora. To ukazuje da ovi zagrejači sa drugačijom konstrukcijom gorionika od komercijalnih, omogućavaju efikasnije zagrevanje usisnog vazduha. Broj otvora na gorioniku zagrejača ima direktan uticaj na plamen odnosno na pouzdano startovanja dizel motora.

Ključne reči: *zagrejač, konstrukcija, gorionik, otvori, plamen.*

* Kontakt autor. E-mail adresa: zlatabracanovic@mts,rs

Projekat: TR-35039 Istraživenje i primena naprednih tehnologija i sistema za poboljšanje ekoloških, energetskih i bezbedonosnih karakteristika domaćih poljoprivrednih traktora radi povećenja konkurentnosti u EU i drugim zahtevima tržišta

UVOD

Brojna laboratorijska i eksploataciona ispitivanja zagrejača ukazuju da različite konstrukcije i sastavi materijala pripadajućih delova zagrejača imaju značajan uticaj na pouzdano startovanje dizel motora pri sniženim temeraturama okoline [1-3]. Shodno tome cilj ovog istraživanja usmeren je na povećanje efikasnosti samog zagrejača, kako bi se obezbezbedila dodatna toplota usisnom vazduhu u usisnoj grani dizel motora, dovoljna za efikasno i sigurno startovanje u realnim hladnim vremenskim periodima [4]. Realizacija daljeg istraživanja zasnovana je na izmeni konstrukcije gorionika zagrejača odnosno promeni broja otvora [5]. Kako bi se pratio plamen zagrejača u kontinuitetu usledila je adaptacija usiane grane dizel motora, koja podrazumeva perforaciju potrebnog otvora i postavljanje kaljenog stakla. Istovremeno u usisnoj grani dizel motora ugrađena su tri adaptera za senzore temperatura, da bi se pratio gradijent porasta temperaturne [6].

Ispitivanje je obuhvatilo veliki broj uzoraka komercijalnih zagrejača čiji gorionik ima osam rupa u jednom redu. Svi uzorci zagrejača su pre ugradnje na dizel motor predhodno laboratorijski ispitani. To je imalo za cilj određivanje tehničko–funkcionalnih karaktristike prema propisanoj proceduri i zadatim kriterijumima, da bi se dobila potvrda upotrebnog kvaliteta odnosnih zagrejača [7, 8].

Definisan je odgovarajući algoritam radi iznalaženja mogućnosti većeg protoka vazduha zbog sagorevanja male količine dizel goriva, potrebne za aktiviranje zagrejača. Usledili su proračuni koji su ukazali da gorionik zagrejača sa šesnaest otvora raspoređenih u dva reda ima zadovoljavajući protok vazduha, te stoga može da formira kvalitetniji plamen neophodan za zagrevanje vazduha u usisnoj grani dizel motora [9].

Uzorci zagrejača sa gorionikom od šesnaest otvora su prvo ispitivani laboratorijski kako bi se utvrdio upotrebni kvalitet istih i odredile tehničko-funkcionalne karakteristike prema zadatim kriterijumima i zahtevima [10]. Dalji tok istraživanja, kao što je rečeno, odnosi se na ugradnju uzoraka ispitanih zagrejača u labaratorijskim uslovima, potom ugradnju na dizel motor, po već zadatoj metodologiji.

Merno regulacionom opremom za ispitivanje zagrejača uz podršku PC računara je omogućeno praćenje i beleženje svih zadatih i potrebnih mernih veličina tokom laboratorijskog ispitivanja [11]. Kontinualno se vrši posmatranje promena mernih veličina, kontrola i nadzor parametara mernih jedinica u zavisnosti od metroloških zahteva [12]. Istovremeno je obezbeđen proces nesmetanog importovanja svih podataka za dalje matamatičke obrade i analize sa ciljem konačne verifikacije posmatranog proizvoda [13]. Ova laboratorijska istraživanja su pokazala da je upotrebom zagrejača sa gorionikom od šesnaest otvora ostvareno poboljšano startovanje dizel motora a time je povećana pouzdanost rada dizel motora pri niskim temepraturama spoljne okoline.

MATERIJAL I METODE RADA

Radna sposobnost zagrejača predstavlja, na određen način, meru sposobnosti zagrejača za vršenje postavljene funkcije kriterijuma u datom vremenu, datim uslovima i uticajima poremećaja u procesu rada dizel motora [1]. Da bi započelo sagorevanje goriva kod dizel motora neophodo je radni fluid, smešu vazduha i goriva, ubrizganog u prostor sagorevanja nakon kompresije, zagrejati do temperature više od temperature paljenja

goriva [2]. Toplota za zagrevanje goriva obezbeđuje se, pre svega, tokom kompresije. Međutim, kako radni proces u dizel motoru nije adijabatski postoji stalna razmena toplote između goriva i zidova cilindra u kojem se proces obavlja [3]. Imajući u vidu ovu razmenu toplote jasno je da pri izuzetno niskim temperaturama postoji opasnost da se gorivo tokom kompresije ne zagreje do temperature koja odgovara tački samopaljenja. Na realnim dizel motorima ovo je često slučaj, naročito u zimskim uslovima eksploatacije [4]. Shodno tome neophodno je obezbediti dodatno zagrevanje goriva da bi započeo proces sagorevanja**.**

Za ovo istraživanje odadrani uzorci komercijalnih zagrejača, pre ugradnje na dizel motor, su ispitani u laboratorijskim uslovima, kako bi se dobile tehničko-funkcijonalne karakteristika zagrejača prema definisanim uslovima ispitivanja. Ova ispitivanja imaju za cilj da se dobijene vrednosti funkcijonalno-tehničkih karakteristika zagrejača uporede sa tehničkim kriterijumima za ocenu upotrebnog kvaliteta, datih u Tab. 1., koje predstavljaju valjanost zagrejača i dozvoljvaju upotrebu i ugradnju istih u dizel motore.

Tabela 1. Tehnički uslovi i kriterijumi za vrednovanje kvaliteta zagrejača
Table 1. Technical requirements and criteria for evaluating the quality of the heater

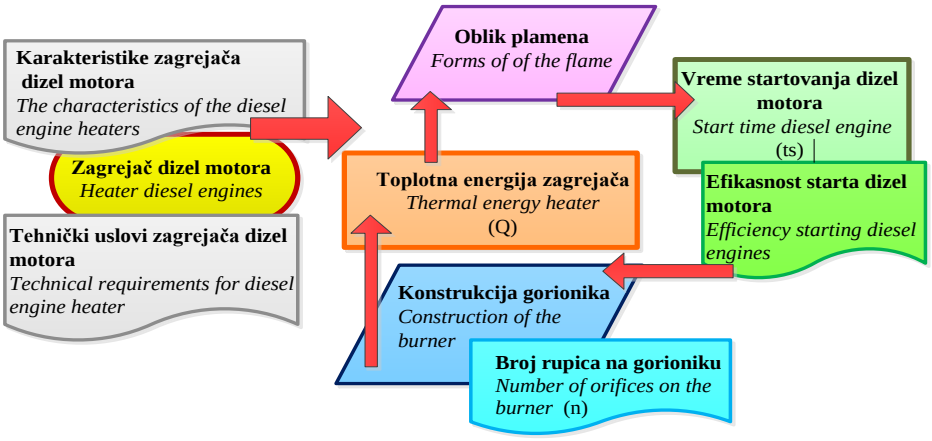
Tehnički uslovi zagrejača za dizel mtore / *Specifications for Diesel Motor Heaters*	
Napon napajanja / *Supply voltage heater*	U=11,5(V)DC
Pritisak goriva / *Fuel pressure column*	P=0,3(bar)
Gorivo / *Fuel*	Dizel / *diesel*
Tehnički kriterijumi za procenu kvaliteta zagrejača za dizel motore *Technical criteria for assessing the quality of diesel engine heater*	
Vreme paljenja zagrejača / *Time ignition heater*	$t_p = \leq 14$(s)
Jačina struje grejača / *Current strength heater*	I =12÷13,4(A)
Protok goriva grejača / *Fuel flow heater*	V=3,5÷5,5(mil/min)
Zaptivenost zagrejača / *Tightness heater*	Ne sme propuštati: dim, gorivo, vazduh *It must not permeable: smoke, fuel, air*
Oblik plamena zagrejača *Flame shape heater*	Jak, vretenast, ravnomeran *Strong, spindle, steady*

Po završetku laboratorijskog testa, zagrejači su sukcesivno ugrađivani na dizel motor koji je postavljen na probni sto za ispitivanje motora [5]. Nakon provere svih relevantnih parametara i mernih sistema prišlo se startovanju dizel motora na način propisan metodologijom ispitivanja i dobijeni rezultatai su kasnije sistematizovani i analizirani na uniforman i korelativan način [6].

Pokazalo se da komercijalni zagrejači sa osam otvora na gorioniku, koji se inače ugrađuju na dizel motore, u hladnim vremenskim uslovima nisu uvek pouzdani. Usled velikog broja pokušaja startovanje dizel motora, smanjena je sigurnost i efikasnost startovanje dizel motora, što dovodi u pitanje i trajnost akumulatora [7].

Dalji tok istraživanja nastavljen je pomoću algoritama datog na Sl. 1., koji je omogućio prikaz uticaja aktivne površine gorionika zagrejača na kvalitet plamena i veću ukupnu toplotnu energije zagrejača, u cilju povećanja temperature usisnog vazduha odnosno realizaciji efikasnosti dizel motora kao i samog zagrejača. Na osnovu svih relevantnih podataka pristupilo se izmeni konstrukcije gorionika zagrejača odnosno

perforaciji već izabranih i ispitanih uzoraka zagrejača. Perforacija je podrazumevala da se pored postojećeg reda od osam rupa doda još jedan red od osam rupa. Shodno tome, nove konstrukcija gorionika zagrejača ima šesnaest rupa ravnomerno raspoređenih u dva reda.



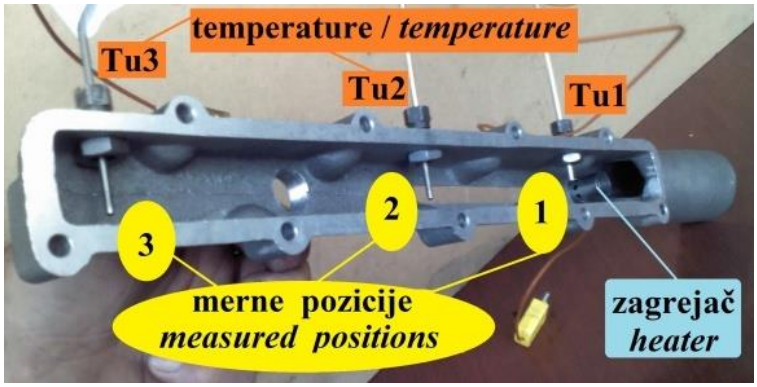
Slika 1. Algoritam za konstruisanje gorionika zagrejača dizel motorta
Figuret 1. Algorithm for constructing the burner heater diesel engine

Zagrejač sa gorionikom od šesnaest otvora treba da ostvari jači plamen i obezbedi veću toplotu usisnog vazduha a samim tim veće temperature vazduha u usisnoj grani dizel motora. Perforacijom površine gorionika zagrejača, sa osam otvora na šesnaest, ostvaruje se veći protok vazduha za sagorevanje goriva potrebnog za aktiviranje zagrejača.

Kako bi se nesmetano pratio oblik plamena pristupilo se adaptaciji usisne grane dizel motora. Odabran je dizel motor DM34, iz razloga što ima ravniju usisnu granu prilagodljivu za potrebnu adaptaciju. Adaptacija usisne grane prikazana je na Sl. 2.

Slika 2. Adatacija usisne grane dizel motora
Figure 2. Adaptation of the intake manifold of diesel engine

Otvor na usisnoj grani prekriven je kaljenim staklom koje je otporno na visoke temeperature. Staklo je zalepljeno pomoću specijalnog lepka koji je takođe otporan na visoke temperature. Ova adaptacija usisne grane dizel motora tokom laboratorijskog ispitivanja omogućila je kontinualno praćenje oblika plamena zagrejača, bitnog za ocenu kvaliteta zagrejača. Istovremeno na usisnoj grani dizel motora postavljeni su odgovarajući adapteri za ugradnju tri senzora potrebna za merenje temperature, kao što se videti na Sl. 3.



Slika 3. Usisna grana dizel motora sa ugrađenim senzorima za merenje temperature
Figure 3. Intake manifold diesel engine with embedded sensors for temperature measurement

Na prvoj mernoj poziciji u usisnoj grani dizel se meri temperatra usisnog vazduha Tu1(°C) kod samog zagrejača odnosno u pravcu prvog cilindara dizel motora. Na drugoj mernoj poziciji se meri temperatura usisnog vazduha i obeležena je sa Tu2(°C) koja je u pravcu drugog i trećeg cilindra dizel motora. Treće merna pozicija je predviđena za merenje temperature usisnog vazduha i obeležena je sa Tu3(°C) i u pravcu je četvrtog cilindra dizel motora.

Laboratorijska ispitivanja tehničko-funkcionalnih karaktristika zagrejača za dizel motore sprovedena su upotrebom savremene merno-regulacione opreme, zahvaljujući novim tehnologijama, uz kompletnu podršku PC računara tokom ispitivanja [8,9]. U prvom delu laboratorijskog istrživanja odabrani i ispitani uzorci komercijalnih zagrejača za dizel motore sa gorionikom od osam otvora sukcesivno su ugrađivani u dizel motor. Merene su i beležene temperature u usisnoj grani na tri merne pozicije: Tu1/8, Tu2/8 i Tu3/8(°C). Drugi deo istarživanja odnosi se na ugradnju istih zagrejača sa perforiranim gorionikom, sa osam na šesnaest otvora. Takođe su merene temperatura u usisnoj grani na tri merne pozicije koje su obeležene sa: Tu1/16; Tu2/16 i Tu3/16 (°C). Prvi broj označava merenu poziciju u usisnoj grani /1,2 i 3/, dok drugi broj definiše broj otvora na gorioniku zagrejača /8 i 16/.

Metodologija za startovanje dizel motora u potpunosti odgovara uslovima eksploatacije rada dizel motora u realnim uslovima eksploatacije. Dalji tok istraživanja podrazumeva posmatranje i beleže sledećećih mernih veličina: vreme pojave plamena t_p(s) odnosno vreme uključenja zagrejača; vreme protoka drugog i trećeg mililitra goriva t_{23}(s), pri upotrebi goriva dizel D2 predhodno laboratorijski ispitanog; vreme startovanje dizel motora t_s(s); temeperatura ambijenta T_a(°C) [10].

REZULTATI ISTRAŽIVANJA I DISKUSIJA

U ovom radu analizirane su vrednosti izmerenih temeperatura usisnog vazduha na tri merne pozicije: Tu1/8, Tu2/8, Tu3/8, Tu1/16, Tu2/16 i Tu3/16 u usisnoj grani dizel motora, za dva slučaja gorionika zagrejača, i uneti na verovatnosni papir [11,12]. Aproksimimacijom prave linija između unetih tačaka metodom najmanjih kvadrata, određeni su parametri Weibull-ove raspodele oblika β i razmere η, čije su vrednosti za sve temeperature prikazane u Tab. 2., za tri merne pozicije u usisnoj grani dizel motora pri upotrbi diferentnih gorionika zagrejača.

Tabela 2. Parametri Weibull-ove raspodele temeperature u usisnoj grani dizel motora
Table 2. Parameters Wejbull's temerature distribution of air in the intake manifold diesel engine

Parametri Weibull-ove raspodele temeperature za merne pozicije *Parameters of Weibull's distribution of temperature for measuring positions*		1		2		3	
		β	η	β	η	β	η
Broj rupice na gorioniku zagrejača	8	13	175	14	148	15	120
Number of orificess in the burner heater	16	19	200	28	165	27	148

Gustina raspodela posmatranih vrednosti za temeprature u usisnoj grani dizel motora je primenjena je za dva slučaja, kada je zagrejač sa gorionikom od osam otvora i sa šesnaest otvora, a data po Weibull-u kao funkcionalna zavisnost na osnovu formule (1).

$$\mathrm{f(T)} = \left(\frac{\beta}{\eta}\right) \cdot \left(\frac{T}{\eta}\right)^{\beta-1} \cdot e^{-\left(\frac{T}{\eta}\right)^{\beta}} \tag{1}$$

Na osnovu analiza dobijenih rezultata može se konstatovati da su dobijeni rezultati visokog nivoa poverenja što omogućuje donošenje konačnih i validnih zaključaka. Jasno se uočava da je faktor oblika β Weibull-ove raspodele za sva tri slučaja izuzetno visok a posebno kod primene zagrejača sa gorionikom od 16 otvora [13]. Drugim rečima to znači da je rasipanje vrednosti oko srednje vrednosti dovoljno malo .

U Tab. 3. date su vrednosti izmerenih minimalnih i maksimalnih temepratura na tri merne pozicije u usisnoj grani dzel motora pri upotrebi različitih gorionika zagrejača.

Tabela 3. Temperature na mernim pozicajama u usisnoj grani dizel motora
Table 3. Temperature at the measurement position of an inlet manifold diesel engine

dizel D2 *diesel D2*		Izmerene temperature na mernim pozicijama T(°C) *The measured temperature at the measuring positions*	**1**	**2**	**3**
Broj otvora na gorioniku zagrejača *Number of orificess in the burner heater*	**8**	T min	150	129	105
		T max	198	172	127
	16	T min	188	159	136
		T max	213	189	159

Analizirajući prikazane vrednosti temepratura na mernim pozicijama može se reći da je pad temperature od prve do treće pozicije u usisnoj grani dizel motora kod gorionika zagrejača sa 16 otvora 33,96 %, dok za zagrejače sa gorionikom od 8 otvora pad temperature je 55,90%. Veći pad temeparature zači manja efikasnost odnosnog zagrejača.

Pri startovanju dizel motora, u usisnoj grani zagrejač formira plamen u kratkom vremenskom trajanju od t=1÷3 (s) koji se prostire duž usisne grane i tako zagreva usisni vazduh. Koliko će plamen uspeti da zagreje usisni vazduh na mernoj poziciji 3-tri u usisnoj grani dizel motora zavisi od jačine, vremenskog trajanja i dužine prostiranja plamena. Toplota koju uzrokuje kratko trajanje plamena zagrejača rasipa se na zidove usisne grane, na vazduh koji konstantno ustrujava u usisnu granu i prema cilindrima dizel motora. U Tab. 4. prikazani su oblici plamena u usisnoj grani dizel motora pri upotrebi zagrejača sa različitim gorionikom.

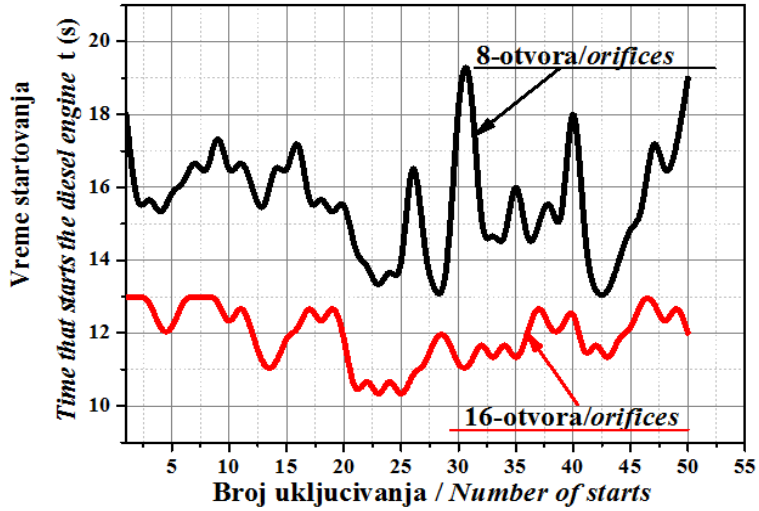
Tabela 4. Uticaj konstrukcije gorioniku zagrejača na kvalitet plamena
Table 4. Influence construction burner heaters on the quality of the flame

dizel D2 *diesel D2*		Gorionikom zagrejača *Burner heater*	Plamena u usisnoj grani *The flame in the inlet manifold*
Broj rupica na gorioniku zagrejača *Number of orificess in the burner of heater*	**8**		
	16		

Može se videti iz priloženih slika da je plamen kod zagrejača čiji gorionik ima šesnaest otvora jak, difuzan, snažan sa malo ejektorskog sagorevanja i većom dužinom prostiranja u odnosu na zagrejače sa gorionikom od osam otvora. Ovakav plamen zagrejača odgovara tehničkim zahtevima o upotrebnom kvalitetu uzoraka zagrejača, kao takav uzrokuje veće temeperature duž usisne grane dizel motora. Time je povećana efikasnost startovanja dizel motota, naročito u hladnim vremensim uslovim.

Vreme startovanja dizel motora ts (s) beleženo za sve uzorke zagrejača u toku svih uključenja dizel motora. Na Sl. 4. prikazan je dijagram startovanja dizel motora sa upotrebom zagrejač različih gorionika a odnosi se, u ovom primeru, na pedeset uključenja dizel motora.

Na dijagramu se može videti da dizel motor ima kraće vreme startovanjea ts (s) pri upotrebi svih uzoraka zagrejača sa gorionikom od šesnaest otvora u odnosno na uzorke zagrejača sa gorionikom od osam otvora. U u Tab. 5. data su vremena startovanja dizel motora za različite gorionike zagrejača.



Slika 4. Broj uključivanja i vreme startovanja dizel motora sa različitim gorionikom zagrejača
Figure 4. Number of connections and the start time of diesel engines with different burner heater

Tabela 5. Vreme startovanja dizel motora sa različitim gorionikom zagrejača
Table 5. Starting time diesel engine with different burner heater

dizel D2 *diesel D2*		Vreme startovanja dizel motora *Time that starts the diesel engine* t (s)	
		t min	t min
Broj rupice na gorioniku zagrejača *Number of orificess in the burner heater*	**8**	13	18
	16	10	14

Primenjena metodologija istraživanja je pokazala da se na osnovu izabranih mernih sistema i odabranih kriterijuma mogu dobiti relevantni podaci za ocenu uspešnosti odnosnog istraživanja i da se dobijeni rezultati mogu analizirati sa visokom pouzdanošću i visokim nivoom povrenja.

ZAKLJUČAK

Istraživanje efikasnosti zagrejača za dizel motore sa dva diferentna gorionika sprovedena u ovom radu pokazuju sledeće :

- Zagrejač sa gorionikom od šesnaest otvora pruža jasan difuzan plamen koji prenosi dovoljno toplote na usisni vazduh za sve cilindre dizel motora, čime se postiže stabilno, pouzdano i efikasno startovanje samog motora.
- Sa sigurnošću se može zaključiti, na osnovu spovedenih analiza izmerenih temepratura duž usisne grane, zagrejači sa gorionikom od šesnaest otvora ostvaruju manji pad temeperature u odnosu zagrejače se gorionikom od osam otvora. Manji temperaturni pad se pozitivno odražava na startovanje dizel motora u hladnijim vremenskim uslovima.

- Obavljeni proračuni i teorijske analize dokazale su da se zagrejač sa gorionikom od šesnaest otvora pokazao veoma uspešnim i time povećao efikasnost startovanja dizel motora u realnim hladnim uslovima eksploatacije. U prosečenom korelativnom odnosu može se konstatovati da je poboljšanje preko 17%.

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THE IMPORTANCE OF AN EFFICIENT WORK OF DIESEL ENGINES HEATERS

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Abstract: Heater diesel engines, with the flame heating, a system that facilitates starting the diesel internal combustion engines, especially in cold weather. In order to find opportunities to increase the temperature of the intake air of diesel engines, was followed by a study of the new construction of the burner heater using a specified algorithm. Intake manifold of diesel engine wes adapted to watch the propagation of flame heater and assessment the quality.This experiment was conducted using the methodology already developed for laboratory testing of the technical and functional characteristics of the heater using modern systems for measurement, data acquisition and process monitoring tests.Studies have shown that shorter start the diesel engine when using the heater with the burner of the sixteen orifices.This indicates that these heaters with a different frame of commercial burner, enabling more efficient heating of the intake air.The number of orifices in the burner of the heater has a direct impact on the flame or to reliably start diesel engines.

Key words: *heater, construction, burner, orificess, flame heater*.

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DEVELOPMENT AND EVALUATION OF A TRACTOR OPERATED pH MONITORING SYSTEM

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***Abstract*:** South-western and central part of Punjab is dominated by calcareous soil includes desert soil, sandy loam to clayey and also have grey and red desert soil, calsisol soil, regosol soil and alluvial soil making alkalinity and salinity problematic as the power of hydrogen (pH) value of soil varies from 7.8 to 8.5 in this zone. Reduction-oxidation potential or 'Redox' is a measure of the electrical state of soil indicating the chemical condition of several substances and measure soil nutrient availability significant for plant growth. It varies with the relative acidity of the soil, and for purpose of comparison, Redox is expressed in milli volts (mV). pH monitoring system need to be developed which will help in mechanization of field operation by providing real time and online values of soil pH and mV, thus helping the researchers and farmers to start precision farming in the area. To achieve this, a tractor operated pH monitoring system was developed and evaluated in the field to measure the soil pH and mV along with geo-referenced locations. On an average soil pH of selected field was measured 6.55 with coefficient of variation (CV) 7.0%. Average soil mV was 40.71 having coefficient of variation (CV) 56.1. The model developed between pH and mV showed that there was a good co-relation between soil pH and mV having R^2=0.89 indicating that soil pH was basically the reduction oxidation potential of soil.

Key words: *ph monitoring system, ph meter, GPS, bund former, soil mV*

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INTRODUCTION

Punjab is produced about two-third of the food grains produced annually in India due to its fertile soil. Climatic differences result in varieties of soil which helps to cultivate a wide range of crops and vegetation in Punjab. The soil in Eastern Punjab is loamy to clayey and in South-western and central part of Punjab the area is dominated by calcareous soil includes desert soil, sandy loam to clayey and sierozem soil and also have grey and red desert soil, calsisol soil, regosol soil and alluvial soil making alkalinity and salinity problematic for this place. The alluvial soil of this zone can be widely described as arid and brown soil or tropical arid brown soil. The electrical conductivity of soil measured by tractor mounted soil sensor varied from 8.5 to 9.6 $mS \cdot m^{-1}$ having coefficient of variance 26.8% at soil moisture content of 26% (wb) [1]. The Power of hydrogen (pH) value in this zone ranges from 7.8 to 8.5 [2]. Power of hydrogen (pH) measures the activity of the (solvated) hydrogen ion concentration and is often written as pH. Pure water has a pH very close to 7 at 25°C. Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline. Soil pH determined by using different methods and devices such as concentration cell with transference, a glass electrode and a pH meter, or using indicators. Specialty meters and probes are available for use in special applications, harsh environments, etc.

A study was conducted to determine Cd, Ni, Zn, Cu, Mn, Cr, Al and Se contents in spring wheat, potatoes and carrots (Cd, Ni and Zn) and estimate their correlations with certain soil factors (surface and subsurface soil pH and organic matter content) governing the plant availability of these elements. Concentrations of Zn, Mn, Ni (grain) and Cd (straw) in spring wheat (n=43); Cd, Ni, Zn, Mn, Cu and Al in potatoes (n=69); and Cd, Ni and Zn in carrots (n=36) showed significant negative correlations with surface soil pH (0–25 cm). The Se content of potatoes and Cr content of spring wheat straw were positively correlated with soil pH [5].

Reduction Oxidation Potential (ORP) or Redox is the activity or strength of oxidizers and reducers in relation to their concentration. Oxidizers (chlorine, bromine) accept electrons; reducers (sodium sulfite, hydrogen sulfide) lose electrons. Like acidity and alkalinity, the increase of one is at the expense of the other. Reduction-oxidation potential is a measure of the electrical state of soil indicating the chemical condition of several substances significant for plant growth. ORP is simply a measure of the availability of soil nutrients, particularly nitrogen. It varies with the relative acidity of the soil, and for purposes of comparison it is useful to express the 'Redox' in milli volts (mV).

It was reported that Hand held Ion Selective Electrodes (ISE) were commercially available for testing pH, sodium (Na), potassium (K), and nitrate-nitrogen (NO_3-N) [6] and [7] used a pH meter to measure the soil pH and correlated pH values to find the growth and soil nutrients of Cunninghamia lanceolata plantation, evergreen coniferous broadleaf mixed plantation and evergreen broadleaf mixed plantation.

The methods used by different scientist to measure soil pH and mV in laboratory is expensive and labour intensive as the pH measuring devices and equipments are not installed on the machines. Due to which, the soil samples are collected and bring in Laboratory manually to calculate the soil pH. Hence, there is a need to develop a machine with pH meter installed on it which will help in mechanization of field operation by providing real time and online values of pH and mV of soil, thus, helping

the researchers and farmers to start precision farming in the area. As a consequence, cost expenditure on human labour could be saved. It will indicate the protective measures to be taken so that the pH of soil can be neutralized to the permissible limits conducive for the plant growth. To achieve the goal, a tractor operated pH monitoring system was developed and evaluated in the field to measure the soil pH and mV.

MATERIAL AND METHODS

The basic requirements for the development of soil pH monitoring system were Bund maker/Furrow maker, pH meter with data logger and GPSS (Global Positioning Satellite System) for the measurement of different parameters such as soil pH, temperature, latitude, longitude and milli volts in the field.

Selection of the equipment/instrument. A single furrow forming tractor operated bund maker for mounting of pH meter was selected due to safely fitting of probe on it and also had enough space for placing the pH meter and Global Positioning Satellite (GPS) system. The bund maker consists of mild steel angle iron frame, hitch system, and two blades used for bunds making for efficient use of irrigation water. Moreover, the depth of soil dugged by bund maker was up to 30 cm operated by 35 HP tractor. The blades and blades angle are adjustable along the frame to vary bund width and bund height. The Field scout pH 110 meter make, Spectrum Technologies, Inc., U.S.A was selected to mount over the bund maker. Garmin 76csx GPS system was selected due to its compatibility with field scout ph 110 meter.

pH meter. A special type of pH meter is required for the monitoring system so that instantaneous and real time data can be recorded. The Field scout pH 110 meter was selected to mount over the bund maker. The integrated data logger allows the user to easily collect field data with the pH meter. The logger can be used with or without GPS/DGPS. After a set of data collection, it is transferred to a PC using the Data Acquisition Software. Tab. 1 shows the technical specifications of the pH meter. The selected pH meter was very sturdy to work in severe environmental conditions of the field and suitable to work for all types of soil.

Table 1. Specifications of pH meter

Measurement Capacity	*- 4,096 data points without GPS* *- 1,488 data points with GPS*
Operating Environment	*- Weather Resistant*
Power	*- 4 x AAA batteries* *- Provides 40 hours of logging*
Software Requirements	*- Windows 95 or higher* *- Field Scout Software v. 3.4 or higher (included)*

Development of pH monitoring system. For the development of monitoring system, a platform made up of galvanized iron sheet was fitted in between the frame of Bund Maker. Two metallic boxes of galvanized iron were mounted on the platform for supporting the pH meter and GPS system. Fig. 1 shows the line diagram of designed platform and real view of platform fitted on the bund maker.

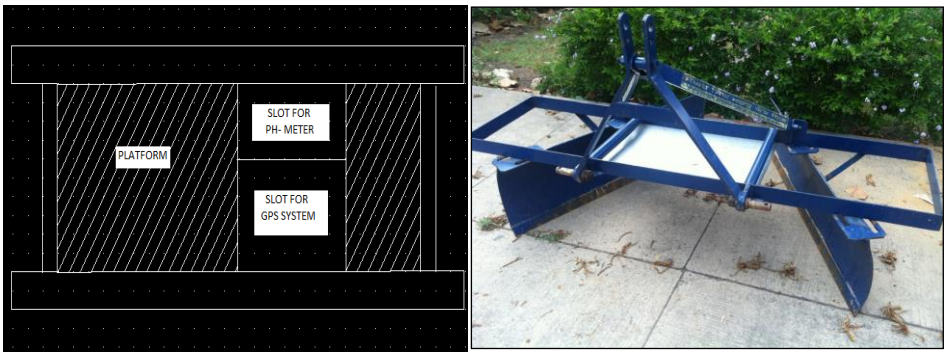

Figure 1. Line diagram of designed platform and real view platform fitting on bund maker

Fig. 2 shows the front view of the implement on which pH meter is mounted and the probe is mounted on the disc vertically.

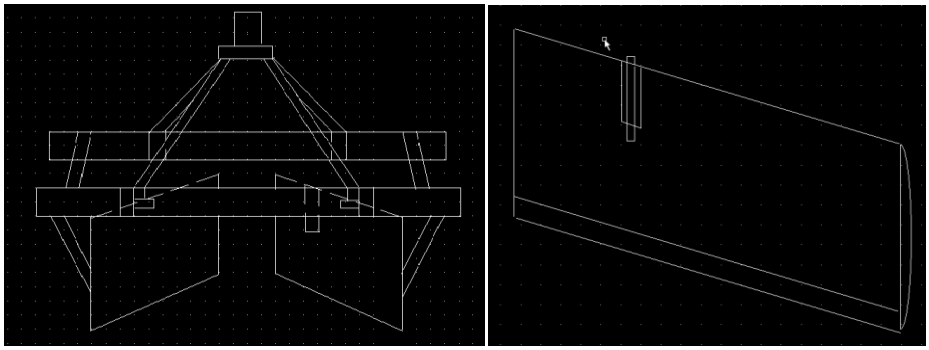

Figure 2. Front view of bund maker with probe fitted vertically

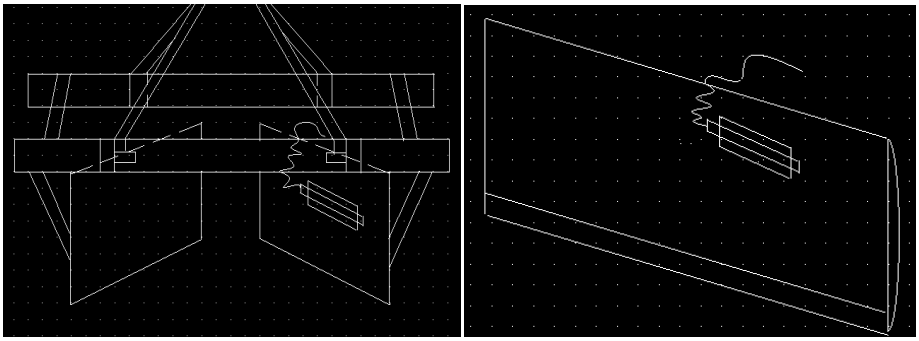

Figure 3. Front view of Bund maker with probe fitted horizontally

A slot type arrangement was made to fix the probe of pH meter on one blade of the bund maker. Initially, the slot of probe was fixed onto the blade of bund maker vertically, but this arrangement was not suitable due to soil impact on the probe. This

huge soil force could have easily damaged the delicate probe and its electrode. It was visualized that mounting of the probe horizontally instead of vertically may receive lesser impact. So keeping in view the probe was fitted horizontally on the blade of the bund maker. The horizontal m**o**unting of the probe with the bund maker is shown in Fig. 3.

Fig. 4 shows the fitting of the pH meter probe on the bund former blade and final design of monitoring system after placing the pH meter and GPS in their respective boxes and Fig. 5 shows the operational view of bund former in the field.

Figure 4. Probe fitting on the bund maker and final design of monitoring system

Figure 5. Operational view of bund maker in the field

Experimental Planning. The field experiments were conducted at the departmental farm. The soil type was sandy loam. The bund maker was operated by using 35 HP tractor. The data of soil pH, Temperature, mV along with latitude and longitude of different points were recorded in the field. The data was repeated after every 5 seconds. The mapping of soil pH and milli volt data was done by using ARC GIS.

Calibration of pH sensor. There was need to calibrate the pH sensor as per local conditions. Therefore, to calibrate the pH sensor for its optimum settings, that was calibrated in Soil Testing Laboratory, Dept. of Soil Sciences, PAU Ludhiana. Three

buffer solutions of having pH 4.0, 7.0 and 10.0 were selected for the calibration purpose. The data recorded during the calibration of the pH sensor is mentioned in Tab. 2.

Table 2. Data during the calibration of pH sensor

pH of buffer solution (standard)	*Before calibration (pH sensor)*	*After calibration (pH sensor)*
4.00	*4.12*	*4.00*
7.00	*7.19*	*6.99*
10.00	*9.87*	*10.02*

To recheck the calibration of soil sensor, the sample of soil was also tested through the conventional method. The average value of soil pH measured with conventional method was 6.56, while average value of soil pH measured with pH sensor was found to be 6.44. both values were comparable and therefore soil pH sensor results were quite accurate and comparable with conventional pH measurement results.

Field Evaluation of Monitoring System. For determining the efficacy of the implement, experiments were conducted in the field located near Punjab Remote Sensing centre, PAU campus. The bund maker/former was operated in the field and formed bunds/furrows and soil started rising. When the probe touched the rising soil, the meter's LCD immediately started to indicate soil pH value. When this value was stabilized, the meter locked on that value and got stored in data logger. If the readings are not being geo-referenced, the green LED will briefly flash off and then back on. If the readings are being geo-referenced and a GPS signal is found, the green LED will turn off for a slightly longer time, then glow steadily. If the readings are being geo-referenced but no GPS signal is found, the LED will flash 3 times, then glow steadily. In this case, the pH reading will be recorded without latitude/longitude values. When the GPS is not connected with the meter, then the data logger records the set of readings and then it can transferred to computer or printer with the help of DAS (Data Acquisition Software). The DAS software is designed for pH 110 to allow you a convenient means of capturing data for future analysis using other software program such as LOTUS 123, EXCEL or DBASE in Windows©. It gives off the sets of readings in a excel sheet.

RESULTS AND DISCUSSION

The developed monitoring system was used to measure the soil pH and Reduction Oxidation potential (mV) of soil with the reference provided through global positioning system (GPS). The geo referenced data of soil pH and mV measured during the evaluation of developed system are discussed below.

Measurement of Soil pH. Soil pH data along with its latitude and longitude are presented in Tab. 2. The table indicates that there is variability in the pH for the small field of about half acre. The maximum pH measured by using pH monitoring system was 7.24 at point having location (N30°54.627' and E75°48.688') and minimum value of pH was observed to be 5.66 at point having location (N30°54.593' and E75°48.681'). On an average soil pH was measured 6.55 with variation of soil pH having coefficient of variation (CV) 7.00. It was also observed that soil temperature was not varying

significantly as the temperature varies from 30-32°C. The soil pH map generated by using ARC GIS software is shown in Figure 6. The map was generated by using different zones of soil pH like 5.66-6.24, 6.24-6.56, 6.56-6.78 and 6.78-7.24.

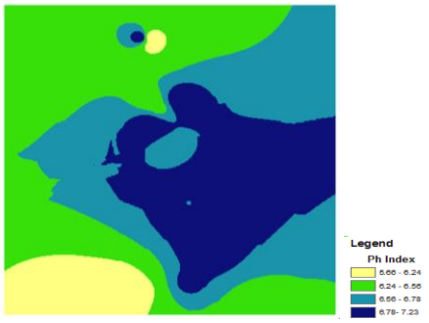

Figure 6. Soil pH map

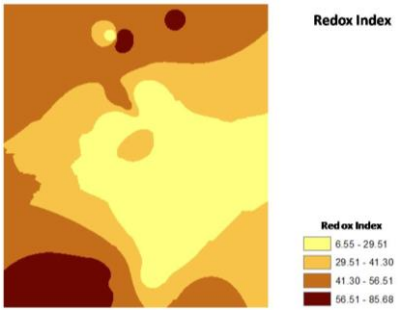

Figure 7. Soil mV map

Table 3. Soil pH and soil mV evaluation results in the field

Reading	*Latitude (N) Longitude (E)*	*Soil pH*	*Soil mV*
1	*30°54.629' 75°48.696'*	*6.51*	*58.9*
2	*30°54.626' 75°48.689'*	*6.07*	*68.1*
3	*30°54.631' 75°48.688'*	*6.49*	*44.6*
4	*30°54.625' 75°48.684'*	*6.48*	*44.3*
5	*30°54.625' 75°48.677'*	*6.37*	*51.9*
6	*30°54.624' 75°48.674'*	*6.34*	*52.2*
7	*30°54.593' 75°48.681'*	*5.66*	*85.7*
8	*30°54.595' 75°48.686'*	*5.82*	*74.4*
9	*30°54.595' 75°48.688'*	*6.16*	*54.9*
10	*30°54.592' 75°48.699'*	*6.35*	*49.0*
11	*30°54.593' 75°48.700'*	*6.37*	*48.7*
12	*30°54.592' 75°48.702'*	*6.44*	*43.6*
13	*30°54.595' 75°48.707'*	*6.52*	*40.5*
14	*30°54.598' 75°48.708'*	*6.66*	*34.1*
15	*30°54.627' 75°48.689'*	*5.84*	*74.1*
16	*30°54.619' 75°48.689'*	*6.28*	*50.6*
17	*30°54.618' 75°48.690'*	*6.44*	*45.9*
18	*30°54.613' 75°48.691'*	*6.60*	*37.1*
19	*30°54.606' 75°48.693'*	*6.77*	*28.5*
20	*30°54.596' 75°48.693'*	*6.90*	*23.3*
21	*30°54.600' 75°48.695'*	*7.17*	*10.8*
22	*30°54.605' 75°48.694'*	*7.18*	*9.0*
23	*30°54.608' 75°48.696'*	*7.22*	*7.4*
24	*30°54.616' 75°48.689'*	*7.22*	*7.3*
25	*30°54.619' 75°48.692'*	*7.22*	*7.3*
26	*30°54.627' 75°48.688'*	*7.24*	*7.2*

Measurement of Soil mV. Soil mV data along with its latitude and longitude are presented in Tab. 3. The table indicates that there is variability in the mV for the small

field of about half acre. The maximum mV measured by using pH monitoring system was 85.7 at point having location (N30°54.593'and E75°48.681') and minimum value of pH was observed to be 7.3 at point having location (N30°54.619' and E75°48.692'). On an average soil mV was measured 40.71 with variation of soil pH having coefficient of variation (CV) 56.1. It was also observed that soil temperature was not varying significantly. The soil pH map generated by using ARC GIS software is shown in Figure 7. The map was generated by using different zones of soil pH like 6.55-29.51, 29.51-41.30, 41.30-56.51 and 56.51-85.68.

Relationship between pH and mV. The relation between pH value and mV value measured in the field is shown in the Fig. 8. The data measured in the field shows that pH and mV have direct relation between them. They are inversely proportional to each other. It means that as the there is increment in the value of pH, there is decrement in the value of mV. The co-relation model was developed between soil ph and mV data i.e. mentioned below:

$$mV = -2.8309*pH + 78.929$$

The model developed between pH and mV shows that there was a good co-relation between soil pH and mV having R^2=0.89. It indicates that soil pH is basically the reduction oxidation potential of the soil.

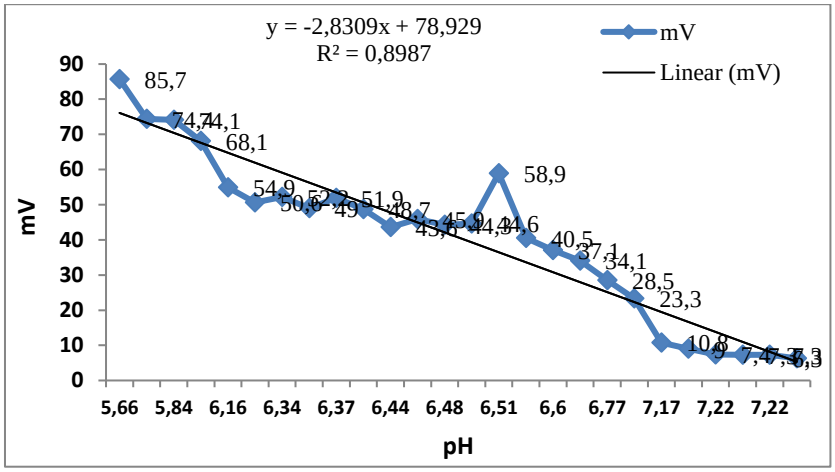

Figure 8. Co-relation model developed between pH and mV

CONCLUSIONS

The conventional method i.e. Laboratory method of soil pH measurement is very laborious and time consuming. Therefore, it is a basic need to develop a system which can measure the real time data of soil pH and soil mV directly in the field. Hence, the tractor operated pH monitoring system was developed by mounting pH meter and GPS on bund former. The pH monitoring system measured pH and mV of soil along with the

geo referenced locations of the points. Following conclusions were drawn on the basis of the study conducted.

- The developed pH monitoring system was capable to measure and store the soil pH and milli volt (mV) data in the system along with the geo referenced locations.
- Average soil pH of selected field was 6.55 with coefficient of variation (CV) 7.0%.
- Average value of soil mV was measured to be 40.71 with coefficient of variation (CV) 55.9%.
- The model developed between pH and mV shows that there was a good co-relation between soil pH and mV having R^2=0.89. It indicates that soil pH is basically the reduction oxidation potential of the soil.
- The pH and mV data of soil up to 30 cm depth was measured by using the developed system as compared to 15 cm soil depth used in the conventional method

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RAZVOJ I ISPITIVANJE TRAKTORSKOG pH MONITORING SISTEMA

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***Sažetak*:** Jugo-zapadnim i centralnim delom Punjaba dominiraju krečnjačka i pustinjska zemljišta, peskovita ilovača, a takođe i crvena pustinjska zemljišta, kalcifikovana zemljišta i aluvijalni nanosi koji dovode do problematične alkalnosti i saliniteta, jer pH vrednost zemljišta varira od 7,8 do 8,5 u ovoj zoni. Redoks potencijal je mera električnog stanja zemljišta koji ukazuje na hemijsku stanje više supstanci i merenje hranljivih materija iz tla značajnih za rast biljaka. Ona varira sa relativnim kiselosti zemljišta. Radi poređenja, Redoks potencijal se izražava u mili voltima (mV). pH monitoring system treba da se razvije da bi omogućio pri radu na terenu u realnom vremenu merenje vrednosti pH zemljišta i mV i tako pomogao istraživačima i poljoprivrednicima da počnu sa primenom precizne poljoprivrede. Da bi se to postiglo, razvijen je sistem monitoringa pH i mV na traktoru na georeferenciranim lokacijama. Na zemljištu sa prosečnom pH odabranih oblasti je izmerena vrednost od 6,55, sa koeficijentom varijacije (CV) 7,0%. Prosečni mV je bio 40.71, sa koeficijentom varijacije (CV) 56.1. Model koji je razvijen između pH i mV pokazao je značajnu korelaciju pH zemljišta i mV sa $R^2 = 0.89$.

Ključne reči: *ph monitoring sistem, ph metar, GPS, zagrtač, zemljišni napon*

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EFFECT OF DRYING ON PHYSICO-CHEMICAL AND NUTRITIONAL PROPERTIES OF FENUGREEK LEAVES

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Abstract: Drying of fenugreek green leaves (*Trigonella foenum-graecum*) was conducted by using desiccant dehumidifier dryer at different temperatures viz. 45, 50 and 55°C. Obtained experimental data including moisture content, rehydration ratio, ascorbic acid and carotenoids were analysed via random factorial scheme. Comparison of data average was carried out with the help of the statistical analysis tool. Statistical analysis of experimental data showed that time, temperature, and their combined effect had a reasonable effect on the drying rate, moisture content, rehydration, ascorbic acid and carotenoids value of dried samples. However, a combined effect of time and temperature on the drying rate was not significant (P>0.05). The lack of fit for rehydration ratio and ascorbic acid was not significant but the values for drying rate, moisture content and carotenoids were significant. The drying rate was 6.37, 7.37 and 7.95 kg water/kg dry matter at drying air temperatures of 45, 50 and 55°C, respectively during first hour of drying (initial moisture content 88.60% wb) and declined afterwards. The results also showed that increasing time and temperature (45, 50 and 55 °C) leads to decrease in ascorbic acid (192.4, 185.3 and 170.6 mg/100g) and carotenoids (25.2, 20.5 and 17.3 mg/100g) of the samples, but it increased the value of rehydration ratio (3.8, 4.0 and 4.5 g/g) of the samples.

Key words*: drying, fenugreek green leaves, moisture content, rehydration, carotenoids*

INTRODUCTION

Inadequate attention to the post-harvest sector has been resulting in high order of losses (8 to 10 % in grains and 25 to 30% in fruits and vegetables) to the farm produces from the stage of harvesting till their use. The amount of moisture present in the food product is the most important factor in determining the extent of losses in post-harvest phase. It is a proven fact that harvesting of crops at higher moisture content and subsequent drying to safe moisture level leads towards saving of grains to the tune of 6 to 7 percent. Drying and dehydration have been also used as tool for value addition and product development from fruits and vegetables. The main aim of drying products is to

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allow longer periods of storage, minimize packaging requirements and reduce shipping weights. Dried foods are tasty, lightweight, easy to prepare and easy to store and use [1].

Green leafy vegetables are a group of edible leaves that are rich in nutrients such as vitamins and minerals. Some of the vegetables, which fall in this group, are spinach, fenugreek leaves, mustard leaves, mint, and coriander. *Trigonella foenum-graecum* is one of the popular kitchen herbs due to its unique aroma and benefits to human health. Primary processing and packaging of fenugreek has been attempted [2]. Experimental and clinical studies have demonstrated beneficial effects of fenugreek in the control of blood glucose, lipids, and platelet aggregation [3]. The defatted part of the plant is said to be responsible for the anti-diabetic action [4]. Its leaves are used in making poultice for external and internal swellings. Dry leaves are used for flavoring and seasoning also. Leaves are rich in protein, iron and vitamin A. It provides natural food fibre and other nutrients required in human body.

Producing dried products such as green leafy vegetables, fruits and many others are still common with traditional methods. Problems concerned with these methods are the long drying time, chance of microbial contamination of foods due to moisture, the undesirable quality of final products, and etc. By applying desiccant dehumidifier drying method, not only is food quality preserved, but also production time decreases considerably. Throughout history, the sun, the wind, and fire were used to remove water from fruits, meats, grains, and herbs. These are classical drying procedures. Air drying is the most frequently used dehydration operation in the food and chemical industry. The wide variety of dehydrated foods, which today are available to consumers and the interesting concern for meeting quality specifications and energy conservation, emphasize the need for a thorough understanding of the drying process [5]. Drying process in principle is to vaporize the water in the dried material. This process is influenced by temperature, humidity and air velocity of the dryer. In the process of drying air required to heat and dry so that drying time can be shortened, but the air temperature must be adjusted to the properties of dried material.

Hot air dryers such as the desiccant dehumidifier dryer are extensively used for drying biological products at commercial level. The drying time and operational temperature of these dryers have a major effect on the quality of dried product. Desiccant dehumidifier uses desiccant wheel to lower the humidity of air in the drying system. Desiccant wheel has a good ability to absorb water in air [6]. In the process of air through desiccant wheel that is latent and sensible state, where in addition to the air becomes dry; the air will also experience an increase in temperature and decrease in relative humidity [7,8]. Reducing the relative humidity of hot air is one such approach, which increases its moisture-absorbing capacity. This helps in maintaining higher driving force for mass transfer between inner layers and the material surface.

Rehydration process is essential for dried products optimization with respect to increasing their amount and expected quality by consumers [9]. During rehydration, two opposite mass transfer flows are contributed including the water transfer into nutrition and extraction of water-soluble substances in opposite directions. Pretreatment, drying and rehydration conditions result in structural changes in food tissues, affecting quality.

With respect to the importance of the food drying process and obtaining a product with the desired quality and appropriate marketing, optimization of the operational conditions seems to be essential in order to produce dried fenugreek leaves with maximum rehydration capability, which has not been studied so far. Therefore, in this research, in addition to the investigation of fenugreek leaves drying kinetics in terms of temperature and time changes, the effects of these two parameters and their combination on moisture content, rehydration, carotenoids and ascorbic acid of dried fenugreek leaves are studied. Furthermore, Mathematical modelling of this process is investigated using the surface-response method which includes the simultaneous influence of changes

in drying temperature and time on moisture content, rehydration, carotenoids and ascorbic acid of dried fenugreek leaves.

MATERIAL AND METHODS

Fresh fenugreek (*Trigonella foenum-graecum*) leaves (average thickness 0.7 mm) was taken from the fields of Hisar, India. The roots as well as extraneous foreign material were removed and the leaves were washed in water to remove dirt and soil. Fenugreek leaves (2 kg) were used for each experiment and a single layer of the material was spread on five trays in the dryer (Fig. 1). The drying chamber containing five perforated trays was used for drying the samples. In this device, the air velocity was constant and equal to 1.5 m/s. The operational temperature and relative humidity was measured by built-in thermo-hygrometer (accuracy ± 2%) throughout the drying process with temperature range of 20 to 200°C and humidity range from 0-100%.

Figure 1. Desiccant based food dryer

Nine experiments were performed at three temperatures viz. 45, 50 and 55°C. These particular temperatures were selected in order to avoid loss of fresh colour, vitamins and texture during drying. The experiments were performed in triplicates at each temperature and experimental results were recorded. The obtained experimental results include the samples' moisture contents on wet and dry basis, rehydration and later on the dried samples were analysed for carotenoids and ascorbic acid. In order to investigate drying kinetics and moisture content, a dimensionless moisture ratio (MR) parameter was used using the following equation:

$$MR = \frac{M_t - M_e}{M_o - M_e} \tag{1}$$

To calculate the rehydration parameter, the dried sample was placed in a hot water bath at 100°C for 10 minutes. Then, the amount of rehydration was calculated by the equation presented below:

$$R = \frac{A}{B} \tag{2}$$

Ascorbic acid is also known as vitamin-C and it was determined by 2, 6-dichlorophenol-indophenol visual titration method [10] and the procedure for estimation of ascorbic acid is expressed by equation (3);

$$\textit{Ascorbic acid}\ (\text{mg per } 100\ \text{g}) = \frac{A * B * V * 100}{W * aliquot\ of\ the\ extract\ taken} \quad (3)$$

Total carotenoids were calculated by column chromatography after that the readings of optical density were taken by spectrophotometer [11].

$$\textit{Total carotenoids}\ (\text{mg}/100\text{g}) = \frac{OD\ at\ 450\ nm * volume\ made\ up}{250 * weight\ of\ sample} * 100 \quad (4)$$

The obtained experimental data including moisture content, rehydration, carotenoids and ascorbic acid were analyzed via random factorial scheme. The time and temperature combined effects on the moisture content, rehydration, carotenoids and ascorbic acid of the samples were modelled using the surface-response fitting method. The "Design Expert" software (version 9.0) was used for surface-response fitting.

RESULTS AND DISCUSSION

Drying kinematics and moisture content. A few studies [12,13] on dehydration of herbs and spices have been reported. Analysis of the experimental data shows that drying of fenugreek leaves occurs only in the falling rate zone. Drying rate can be defined as moisture content on dry basis in unit of time. Drying rate decreases with time in three experimental temperatures, which is a result of the decrement in moisture content as time passes (Fig. 2). An increase in operational temperature in a certain time, leads to decrement in the moisture content of the samples since the evaporation rate increases with increase in temperature (Fig. 3).

The results of variance analysis of drying rate are listed in Tab. 1. In this table, degree of freedom (DF) and sum of squares for each factor are estimated according to the number of considered levels and the obtained experimental data. The Model F-value of 1513.10 implies the model is significant.Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case B and AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 137.74 implies the Lack of Fit is significant. Probability values have been determined from special tables with respect to the values of some of the above mentioned parameters. So the results of this column in Tab. 1 shows that drying time have a reasonable impact on the drying rate of the samples and their combined effect of time and temperature is not significant.

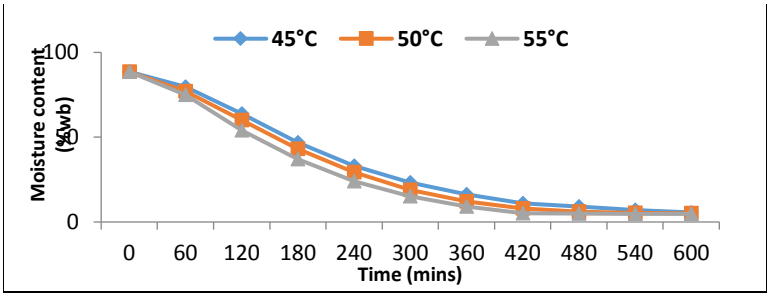

Figure 2. Influence of air temperature on the drying rate of samples in different times

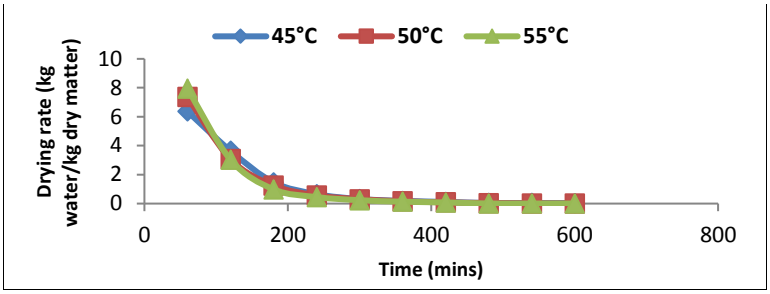

Figure 3. Effect of drying time and temperature on moisture content of the samples

Table1. Effect of different parameters on drying rate with respect to variance analysis

Source	*Sum of Squares*	*DF*	*Mean Square*	*F Value*	*Prob. >F*
Model	*40.58*	*9*	*4.51*	*1513.10*	*< 0.0001 significant*
A-Drying Temp.	*1.537E-003*	*1*	*1.537E-003*	*0.52*	*0.4959*
B-Drying time	*28.02*	*1*	*28.02*	*9401.07*	*< 0.0001*
AB	*0.021*	*1*	*0.021*	*7.01*	*0.0330*
Residual	*0.021*	*7*	*2.980E-003*		
Lack of Fit	*0.021*	*3*	*6.887E-003*	*137.74*	*0.0002 significant*

The results of variance analysis of moisture content are listed in Tab. 2. In this table, degree of freedom and sum of squares for each factor are estimated according to the number of considered levels and the obtained experimental data. The Model F-value of 3258.31 implies the model is significant. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B and AB are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 30750.00 implies the Lack of Fit is significant. So the results of this column in Tab. 2 show that temperature, time, and their combined effect have a reasonable impact on the moisture content of the samples. In this study, the surface-response fitting method was used in order to study the combined effect of time and temperature on the dried sample characteristics. Fig. 4, which shows the surface response of moisture content on wet basis, implies that the moisture content of the samples decreases with increasing time and temperature, although the time variations of the moisture content is less in the final stages of the drying process.

Table 2. Effect of different parameters on moisture content with respect to variance analysis

Source	*Sum of Squares*	*DF*	*Mean Square*	*F Value*	*Prob. > F*
Model	*7729.50*	*9*	*858.83*	*3258.31*	*< 0.0001 significant*
A-Drying Temp.	*78.13*	*1*	*78.13*	*296.40*	*< 0.0001*
B-Drying time	*5962.32*	*1*	*5962.32*	*22620.29*	*< 0.0001*
AB	*17.64*	*1*	*17.64*	*66.92*	*< 0.0001*
Residual	*1.85*	*7*	*0.26*		
Lack of Fit	*1.85*	*3*	*0.62*	*30750.00*	*< 0.0001 significant*

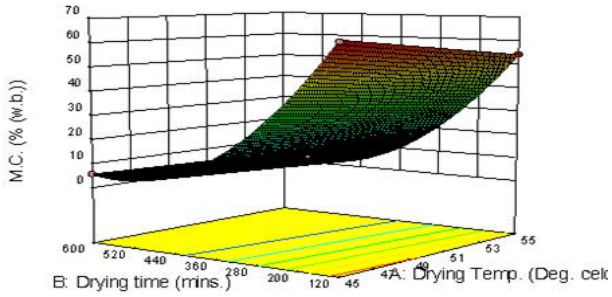

Figure 4. Surface response of moisture content (w.b.) versus time and temperature

Rehydration. Rehydration is a complex phenomenon affected by numerous factors. Important factor that would affect the rehydration is the changing of cell structure during the drying process. Different factors such as temperature, nature of the rehydration process, and type of nutrition [14] impact the rehydration amount. With respect to variance analysis of rehydration which is listed in Tab. 3, time and temperature and their combined effect have a reasonable impact on the rehydration of the samples ($P<0.05$). The Model F-value of 55.83 implies the model is significant. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B are significant model terms. The "Lack of Fit F-value" of 1.01 implies the Lack of Fit is not significant relative to the pure error.

With respect to Fig. 5 which shows the effect of temperature on rehydration, the value of rehydration for desiccant dryer was 3.8, 4.0 and 4.5 g/g at 45, 50 and 55 ºC, respectively. Rehydration has an increasing trend with increasing time and temperature since these two parameters have an increasing effect on the samples rehydration which makes the cellular structure of the samples more porous. Fig. 6 shows the surface-response of the rehydration value. The rehydration value increases with time and temperature, however, temperature has no considerable effect at final temperatures.The required time for reaching a certain value of rehydration decreases with increase in temperature.

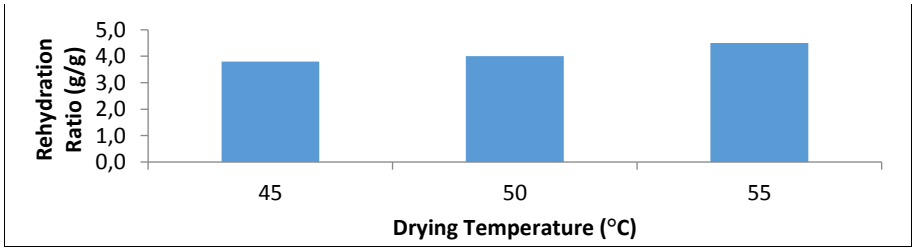

Figure 5. Temperature effect on value of rehydration

Ascorbic acid. With respect to variance analysis of ascorbic acid which is listed in Tab. 4, time and temperature and their combined effect have a reasonable impact on ascorbic acid of the samples ($P<0.05$). The fresh fenugreek leaves contained 209.2 mg/100 g ascorbic acid.

Table 3. Effect of different parameters on rehydration with respect to variance analysis

Source	*Sum of Squares*	*DF*	*Mean Square*	*F Value*	*Prob. > F*

Model	*0.84*	*3*	*0.28*	*55.83*	*< 0.0001 significant*
A-Drying Temp.	*0.12*	*1*	*0.12*	*24.78*	*0.0003*
B-Drying time	*0.72*	*1*	*0.72*	*142.71*	*< 0.0001*
Residual	*0.066*	*13*	*5.045E-003*		
Lack of Fit	*0.046*	*9*	*5.065E-003*	*1.01*	*0.5384 not significant*

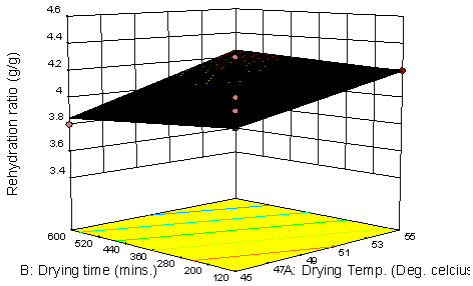

Figure 6. Surface response of rehydration value versus time and temperature

The Model F-value of 264.41 implies the model is significant. Values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case A, B are significant model terms. The "Lack of Fit F-value" of 2.23 implies the Lack of Fit is not significant relative to the pure error. Fig. 7 shows the temperature effect on ascorbic acid of the samples. It is observed from the Fig. 7 that the ascorbic acid retention among the dehydrated samples was 192.4, 185.3 and 170.6 mg/100g at drying air temperatures of 45, 50 and 55˚C respectively.

Fig. 8 shows the surface-response of the ascorbic acid has a decreasing trend with increasing time and temperature since these two parameters have a decreasing effect on the ascorbic acid of the samples. The ascorbic value decreases with increase in temperature.

Table 4. Effect of different parameters on ascorbic acid with respect to variance analysis

Source	*Sum of Squares*	*DF*	*Mean Square*	*F Value*	*Prob > F*
Model	*1086.59*	*3*	*362.20*	*264.41*	*< 0.0001 significant*
A-Drying Temp.	*892.53*	*1*	*892.53*	*651.56*	*< 0.0001*
B-Drying time	*194.04*	*1*	*194.04*	*141.66*	*< 0.0001*
Residual	*17.81*	*13*	*1.37*		
Lack of Fit	*14.85*	*9*	*1.65*	*2.23*	*0.2286 not significant*

Figure 7. Temperature effect on value of ascorbic acid

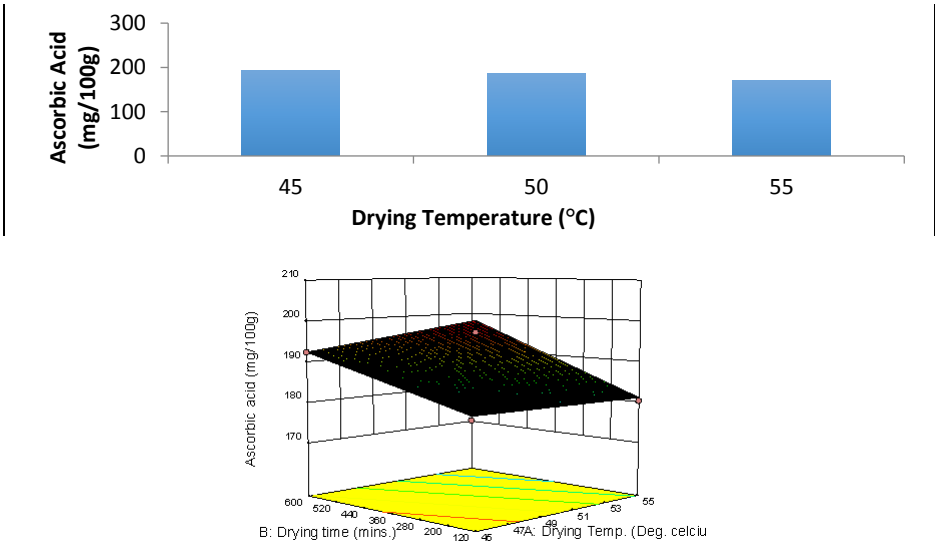

Figure 8. Surface response of ascorbic acid versus time and temperature

Carotenoids. With respect to variance analysis of carotenoids which is listed in Tab. 5, time and temperature and their combined effect have a reasonable impact on the carotenoids of the samples ($P<0.05$). The fresh fenugreek leaves contained 32.4 mg/100g of total carotenoids. Fig. 9 shows the temperature effect on the carotenoids of samples. It was observed that the carotenoids retention among the dehydrated samples was 25.2, 20.5 and 17.3 mg/100g at drying air temperatures of 45, 50 and 55˚C, respectively. Fig. 10 shows the surface-response of the carotenoids have a decreasing trend with increasing time and temperature since these two parameters have a decreasing effect on the carotenoids content of the samples. Fig. 10 shows the surface-response of the carotenoids value. The carotenoids value decreases with increase in temperature.

Table 5. Effect of different parameters on carotenoids with respect to variance analysis

Source	*Sum of Squares*	*DF*	*Mean Square*	*F Value*	*Prob > F*
Model	*155.66*	*3*	*51.89*	*115.24*	*< 0.0001 significant*
A-Drying Temp.	*132.84*	*1*	*132.84*	*295.06*	*< 0.0001*
B-Drying time	*22.78*	*1*	*22.78*	*50.60*	*< 0.0001*
Residual	*5.85*	*13*	*0.45*		
Lack of Fit	*5.65*	*9*	*0.63*	*12.56*	*0.0133 significant*

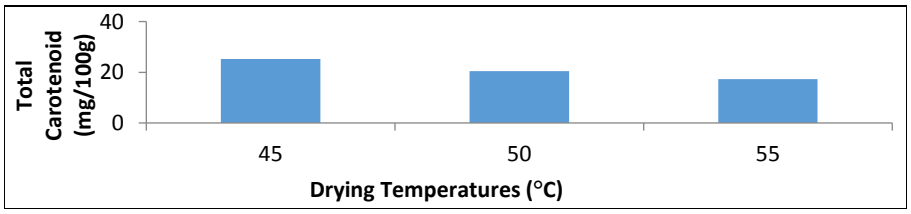

Figure 9. Temperature effect on value of carotenoids

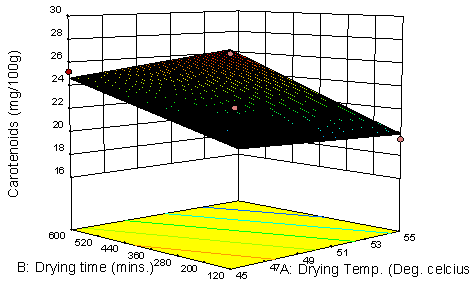

Figure 10. Surface response of carotenoids versus time and temperature

CONCLUSIONS

A low-temperature desiccant based food drying system with temperature and airflow control was presented, evaluated and analysed. Statistical analysis of the experimental data showed that time, temperature, and their combined effect have a reasonable impact on the moisture content, ascorbic acid, carotenoids and rehydration of dried fenugreek leaves ($P<0.05$). However, the combined effect of time and temperature on the value of drying rate was not significant. Drying was conducted at three drying air temperatures of 45, 50 and 55°C. At 45°C the drying time was higher and took 600 minutes to complete the drying. It took 540 and 420 minutes at drying air temperature of 50 and 55°C to dry fenugreek leaves to equilibrium moisture content of 5 % from initial moisture content of 88.60 %. With increase in drying rate and temperature, contractile stresses occur in the cell wall structure which increases the porosity thereby increasing the rehydration ratio. The product dried in desiccant dryer at low temperature (45°C) had superior green colour and maximum retention of ascorbic acid and total carotenoids. From this study it was concluded that desiccant dryer reduced the drying time and gave better quality of dried fenugreek leaves and hence is a promising alternative for food drying. This dryer can be used for drying vegetables like cabbage, eggplant, carrot, and green leafy vegetables.

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UTICAJ SUŠENJA NA FIZIČKO-HEMIJSKA I NUTRITIVNA SVOJSTVA LISTOVA PISKAVICE

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Sažetak: Zeleni listovi piskavice (*Trigonella foenum-graecum*) sušeni su na temperaturama od 45, 50 i 55°C. Dobijeni eksperimentalni podaci, uključujući sadržaj vlage, odnos dehidracija, askorbinske kiseline i karotenoidi su statistički obrađeni. Analiza je pokazala da su vreme, temperatura i njihov kombinovani efekat imali značajan uticaj na brzinu sušenja, sadržaj vlage, dehidraciju, askorbinsku kiselinu i karotenoide suvih uzoraka. Kombinovani efekat vremena i temperature na stope sušenja nije bio značajan (P> 0,05).

Ključne reči: *sušenje, zeleni listovi piskavice, sadržaj vlage, rehidracija, kartenoidi*

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EFFECT OF COLD PLASMA ON MORTALITY OF *Tribolium Castaneum* ON MAIDA FLOUR

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Abstract: Cold plasma is an emerging non thermal processing technology and is one of the novel promising methods for insect mortality. In order to study whether cold plasma could be suitable for control and to investigate the effect of plasma stress on mortality of *Tribolium castaneum*, three treatment variables were used: electrode gap (3 to 5cm), exposure time (1 to 5min) and applied voltage (1000 to 2500V). Mortality rate of an adult was examined after 24h of incubation at 35°C with twenty different treatment combinations as per CCD of RSM. Significant increase in mortality rate of an adult was observed with increase in applied voltage, exposure time and decrease in electrode distance. No significant color change was observed due to plasma exposure on Maida flour using L, a, b color values. This study will pave the way for an effective low temperature treatment technique in stored food product insect management.

Key words*: Non thermal plasma, Tribolium castaneum, mortality, colour*

INTRODUCTION

The red flour beetle, *Tribolium castaneum* is a worldwide insect pest of stored products and processed food commodities. It can infest a variety of products and is perhaps the most economically important insect pest of processed food. Many attempts have been devoted to explore alternative non- toxic pest control methods and one such novel method is cold plasma as it does not leave any chemical residue on the treated

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food products. Atmospheric cold plasma (ACP) is a relatively new technology for microbiological decontamination and sterilization of foods. Due to its unique properties plasma is often referred to as the fourth state of matter according to a scheme expressing an increase in the energy level from solid to liquid to gas and ultimately to plasma [1]. It consists of highly energetic species in permanent interaction including photons, electrons, positive and negative ions, free radicals, and excited or non excited molecules and atoms [2][3][4]. CP can efficiently kill or inactivate bacteria, yeasts, and molds and other hazardous microorganisms, as well as spores and biofilms that are generally very difficult to inactivate [5]. Non thermal antimicrobial treatments of fruits, vegetables and other food produce have been the subject of much research. In the last decade, the atmospheric pressure cold plasma research has greatly increased due to finding important applications in various fields. It is a promising technology that is simple to setup, easy to operate and economical [6].

The non thermal plasma treatment could provide an effective and environmentally friendly treatment in integrated pest management program. The effect of plasma on insects were studied by Bures *et al*. (2005) [7] on green peach aphids and Donohue *et al*. (2006) [8] on western flower thrips, *Frankliniella occidentalis* (pergande); tobacco thrips, *Frankliniella fusca* (Hinds); Asian tiger mosquito, *Aedes albopictus* (Skuse); German cockroach, *Blattella germanica* L. and the two spotted spider mite, *Tetranychus urticae* Koch. Recently Abd El-Aziz *et al.* 2014 [9] also studied the effect of NTP on control of Indian meal moth *Plodia interpunctella* (Lepidoptera: Pyralidae). NTP causes oxidative damage in P. *interpunctella* larvae by generating reactive oxygen stress in their bodies. The recent advances in cold plasma have allowed scientists to successfully develop many different systems, with parameters that can be adjusted for the development of uniform discharge of plasma, such as voltage, electrode distance and exposure time [10]. The objective of this study was to investigate whether cold plasma could be useful for control of *Tribolium Castaneum*, to investigate the effect of plasma stress on mortality of *Tribolium Castaneum* and also to study the colour changes that occur after the treatment on the maida flour.

MATERIAL AND METHODS

The plasma system (Fig. 1) used for the study has been designed and developed indigenously at Indian Institute of Crop Processing Technology consists of two planar electrodes, made of metallic plates and separated by variable gas or air gap [11]. A stainless steel chamber with size of 350x350x350mm and this reactor allows working pressure in the range of near atm to vacuum (under 1 mbar). The distance gap between the two electrodes is mechanically adjusted and reactor is also provided with view glass to see the discharge. The electrodes are covered with Teflon sheets and energized by a high voltage power in the range of 1-40kV and frequency of 50Hz. One of the electrodes is also covered with dielectric barrier, in order to avoid arc between the electrodes.

Experimental Design. Central Composite Design (CCD) of Response Surface Methodology (RSM) were used for the experimental design and plan with independent variables voltage, time and distance between the electrodes. The CCD consisted of three factors with three levels i.e. applied voltage (1000 - 2500 V), exposure time (1 - 5 min) and distance between the electrodes (3 – 5 cm). Table. 1. shows the experimental range

and level for the treatment as used by Markovic *et al*., [12] and the number of experiments required (N) is given by the expression: 2^k (2^3 = 8; star points) + 2 k (2 × 3 = 6; axial points) + 6 (center points; 6 replications). Accordingly, the CCD matrixes of 20 experiments covering the full design of five factors were used for building quadratic models as shown in Table. 2. The experimental data obtained from the CCD model experiments can be represented in the form of the following equation:

$$y = a_0 + a_1 d + a_2 v + a_3 t + a_4 dv + a_5 dt + a_6 vt + a_7 d^2 + a_8 v^2 + a_9 t^2 \quad (1)$$

Where y represents the response function, a_0 is an intercept and d, v, t are independent variables, where a_1 to a_3, a_7 to a_9 and a_4 to a_6 are the coefficients of the linear, quadratic and interactive terms, respectively.

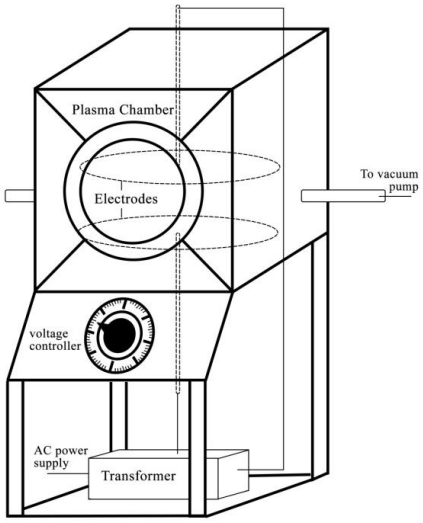

Figure 1. A representation of plasma chamber and electrode connection to the transformer

Table 1. Experimental range and levels of the independent variables

Sl. No	*Independent variable*	*Factor*	*Experimental range and level*				
			-1.68	*-1*	*0*	*1*	*1.68*
1	*Electrode gap (cm)*	*d*	*2*	*3*	*4*	*5*	*6*
2	*Voltage (volts)*	*v*	*500*	*1000*	*1750*	*2500*	*3000*
3	*Exposure time (sec)*	*t*	*0.5*	*1*	*3*	*5*	*7*

Mortality assay. Adult *Tribolium castaneum* was treated inside a plasma chamber as per the experiment designed using CCD. Five insects were taken in 9 x 9 cm LDPE packaging material with 1 g feed and the insects were exposed to plasma with various combinations. It includes distance between the electrode as 2, 3, 4, 5 or 6, exposure time as 1, 3, 5, 7 or 30 s and applied voltage as 500 V, 1000 V, 1750 V, 2500 V or 3000 V. After treatment the packaging material containing insect and maida flour was stored at 35°C for 24 h to assess the mortality.

Table 2. Experimental design and experimental plan

Run	Experimental Design			Experimental Plan		
	Electrode distance (cm)	Voltage (volts)	Exposure Time (Sec)	D	v	t
1	-1	-1	-1	3	1000	1
2	+1	-1	-1	5	1000	1
3	-1	+1	-1	3	2500	1
4	+1	+1	-1	5	2500	1
5	-1	-1	+1	3	1000	5
6	+1	-1	+1	5	1000	5
7	-1	+1	+1	3	2500	5
8	+1	+1	+1	5	2500	5
9	-1.68	0	0	2	1750	3
10	+1.68	0	0	6	1750	3
11	0	-1.68	0	4	500	3
12	0	+1.68	0	4	3000	3
13	0	0	-1.68	4	1750	0.5
14	0	0	+1.68	4	1750	7
15	0	0	0	4	1750	3
16	0	0	0	4	1750	3
17	0	0	0	4	1750	3
18	0	0	0	4	1750	3
19	0	0	0	4	1750	3
20	0	0	0	4	1750	3

Colorimeter test. Hunter lab ColorFlex EZ, 45/00 Color Spectrophotometer (Hunter Associates Laboratory, Inc., Reston, Virgina, USA) was used for the measurement of colour of plasma treated maida flour. Initially the colorimeter was calibrated with the black and white tiles. All the 20 treated maida flour and control sample were analysed and L, a, b values were recorded.

RESULTS AND DISCUSSION

RSM was used for obtaining the relationship between independent variables and the response. The 20 combinations of experiments were carried out and the response for mortality and colour value were observed (Tab. 3).

The multiple regression analysis of the experimental data using RSM revealed that mortality of insect, color of treated maida flour are related by the following second order polynomial equations:

$$y_1 = 30.29 + 21.15A + 23.21B - 5.00C + 15.00AB + 7.27E^{-15}AC + 1.07E^{-14}BC - 2.26A^2 - 2.8B^2 + 7.91C^2 \quad (2)$$

$$y_2 = 90.11 - 0.36A - 0.10B + 0.18C - 0.53AB - 0.45A - 0.53BC - 0.097A^2 + 0.24B^2 + 0.073C^2 \quad (3)$$

Where A, B, C are the corresponding coded factors of the applied voltage, exposure time, distance between electrodes respectively. The diagnostic plots given in Fig. 2. was

used for estimating the adequacy of the regression model and it shows that the data points indicate that neither response transformation was required nor there was any apparent problem with normality. The general perception of straight line is quite clear in the normal probability supporting the hypothesis of normal distribution.

Table 3. Experimental Response

	Factor 1	*Factor 2*	*Factor 3*	*Response 1*	*Response 2*
Run	*A: Voltage*	*B: Exposure time*	*C: Distance between electrodes*	*Mortality of insect*	*Colorimeter L value of flour*
	V	min	Cm	%	
1	*2500*	*1*	*5*	*0*	*91*
2	*1750*	*3*	*4*	*20*	*89.5*
3	*1750*	*3*	*4*	*60*	*90.61*
4	*2500*	*5*	*5*	*60*	*88.53*
5	*1000*	*5*	*5*	*0*	*91.47*
6	*1000*	*5*	*3*	*0*	*90.85*
7	*1750*	*3*	*4*	*60*	*89.64*
8	*1750*	*3*	*4*	*20*	*90.27*
9	*1750*	*3*	*6*	*60*	*90.51*
10	*1750*	*3*	*4*	*20*	*89.82*
11	*2500*	*5*	*3*	*60*	*89.98*
12	*1000*	*1*	*3*	*0*	*89.07*
13	*1000*	*1*	*5*	*0*	*91.52*
14	*2500*	*1*	*3*	*0*	*90.06*
15	*500*	*3*	*4*	*0*	*90.33*
16	*1750*	*3*	*4*	*20*	*90.82*
17	*1750*	*7*	*4*	*100*	*90.88*
18	*1750*	*0.5*	*4*	*0*	*90.65*
19	*1750*	*3*	*2*	*100*	*90.33*
20	*3000*	*3*	*4*	*100*	*89.4*

Interactive effect of processes of independent variables. Using multiple nonlinear regression model (Eqn 2 & 3) three dimensional contour plots were drawn to show the effects of binary combinations of independent variables on the predicted mortality. These plots were shown in Figs. 3, 4 and 5. Fig. 3 shows the integrated effect of distance between electrodes and the applied voltage on mortality. It indicates that at constant distance between electrodes, the increasing applied voltage increases the Mortality of insects and the mortality also increases with the increase in the total exposure time. The combined effect of voltage and electrode gap on mortality is shown in Fig. 4. From the graph it is interpreted that at constant exposure time, the mortality of insects increases with the decrease in the distance between electrodes and the voltage. Fig. 5 shows the interactive effect of exposure time and electrode gap on mortality. It was estimated that at constant voltage, the mortality of insects started increasing with increase in the exposure time and decrease in the distance between electrodes. It was also found that there is no significant difference on the color of plasma treated maida on twenty different treatment combinations and is shown in Tab. 3.

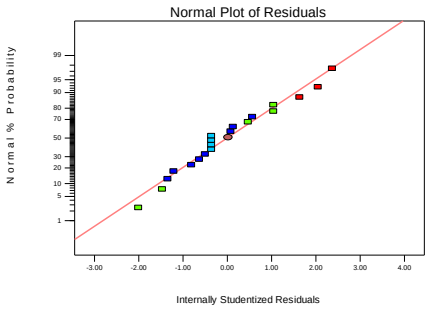

Figure 2. Internally studentized and normal % probability plot of death of Tribolium castaneum

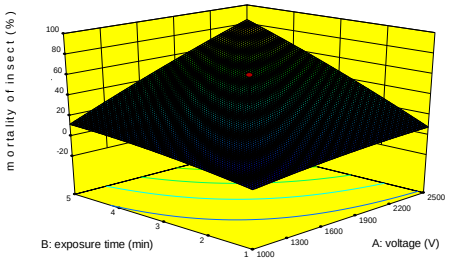

Figure 3. Effect of voltage and exposure time on mortality of insects

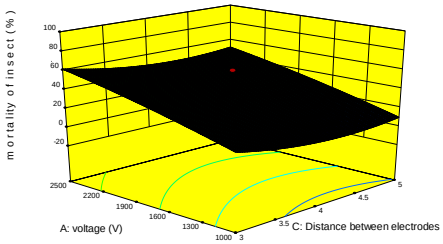

Figure 4. Effect of voltage and electrode gap on mortality of insects

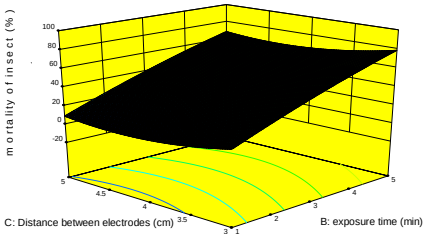

Figure 5. Effect of electrode gap and exposure time on mortality of insect

CONCLUSIONS

Mortality of *Tribolium castaneum* with maida feed was investigated with independent variables like applied voltage, exposure time and electrode gap distance. The results obtained from the experiments clearly indicated that to increase the mortality of insects, either the applied voltage or exposure time have to be increased or distance between the electrodes should be decreased. As cold plasma is a non thermal technique, there is no change in the quality of stored food products. This method is cost effective and can be an alternative for the traditional fumigation technique without any chemical residues. This research showed that cold plasma is an efficient tool for control of *Tribolium castaneum*, however further studies are required in design and development of commercial and continuous cold plasma treatment.

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UTICAJ HLADNE PLZME NA MORTALITET *Tribolium Castaneum* U BRAŠNU

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Sažetak: Hladna plazma je nova tehnologija hladne prerade koja utiče na uginuće insekata . U cilju ispitivanja pogodnosti hladne plazme za kontrolu *Tribolium castaneum* korišćena su tri varijabilna tretmana: zazor elektroda (3 do 5 cm), vreme izlaganja (1 do 5 min) i napon (1000 do 2500V) . Stopa smrtnosti je ispitivana nakon 24h inkubacije na

35°C sa dvadeset različitih kombinacija tretmana kao prema CCD od RSM. Značajno povećanje stope smrtnosti primećena je sa porastom napona, vremena izloženosti i smanjenja zazora elektroda. Nema značajne promene boje zbog izlaganja brašna plazmi. Ova studija će otvoriti put za efikasnu tehniku tretmana niskim temperaturama u skladištu prehrambenih proizvoda radi kontrole insekata.

***Ključne reči**: hladna plazma, Tribolium castaneum, mortalitet, boja*

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DEVELOPMENT AND SELECTION OF SPOONS FOR METERING DEVICE OF ONION BULBLETS PLANTER

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Abstract: Engineering properties of onion bulblets of variety Agrifound Dark Red were determined for development of metering device of onion bulblets planter. The raw sample of onion bulblets was graded in three groups as small, medium and larger size sample according to their diameters (Polar and equatorial). The engineering properties like polar diameter, equatorial diameter, unit weight, geometric mean diameter, sphericity, shape factor and bulk density of onion bulblets of each sample size were determined at 74.00 % m. c. (w. b.) and found as 23.62 mm, 13.2 mm, 1.87 mm, 15.58 mm, 0.66, 0.56 g, 607.82 kg/m^3 respectively for small size sample, 27.9 mm, 19.54 mm, 3.91 mm, 21.30 mm, 0.70, 0.70 g, 664.47 kg/m^3 respectively for medium size sample and 31.58 mm, 28.71 mm, 5.70 mm, 28.64 mm, 0.91, 0.91 g, 685.60 kg/m^3 respectively for large size sample. The angles of repose for small, medium and large size sample were found to be 36.200, 34.210 and 33.510 respectively and values of rolling angle were as 10.21^0, 10.25^0 and 10.45^0 for small, medium and large size samples respectively. The values of shape factor were found as 0.56 (oblate in shape), 0.70 (oblate in shape) and 0.91(spherical in shape) for small, medium and large size sample onion bulblets respectively.

Key words*: onion bulblets, angle of repose, shape factor, rolling angle*

INTRODUCTION

Onion is scientifically known as *Allium cepa L.*, it is a species of family "Amaryllidaceae". It originates in the Yunnan province of China. Onion has been used throughout recorded history for both culinary and medicinal purposes. It has a characteristic pungent, spicy flavor that mellows and sweetens considerably with cooking.

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The production of onion in India is 14.56 million tonnes. In Madhya Pradesh, the total area under onion cultivation is approximately 33720 ha and productivity is 3.713 tonnes /ha. State of Maharashtra has highest area of cultivation (415,000 ha), with a production of 49, 04,000 tonnes. Madhya-Pradesh contributes 1021500 tonnes of onion with 58,300 ha area of cultivation. Though, the productivity of onion in Kerala was found to be highest (16.89 t/ha). The main region behind the reduced yield (3.71 t/ha) per ha in MP may be due to uncertainty in climatic conditions and lower level of mechanization [6].

Production of onions from bulblets is a late Kharif crop. This method is used for getting early crop in the kharif season so as to meet the demand of green onion for salad in early winter. For this purpose, small onion bulblets of kharif onion varieties like Agrifound Dark Red, Baswant 780, N-53 and Arka Kalyan raised in the previous season are used for planting. The best time of sowing of seeds for getting quality bulblets is mid-January to the beginning of February depending upon the area. The plants are left in the nursery bed up to April-May till their tops fall. Harvesting is done along with the tops and selected bulblets (1.0 to 3.00 cm in dia.) are stored till July in a well-ventilated house [6]. Such well stored bulblets are used for planting in the Kharif season.

The farmers are generally sowing onion bulblets by manual method, which is highly labor intensive and time consuming. Therefore, farmers are taking this vegetable/ medicinal crop in very small area. So, there is a need to develop a simple machine that can overcome the difficulty of onion bulblets sowing and reduce the labor requirement and cost of sowing. Generally, the onion seeds are sown in nursery and transplanted in the field with Row to row spacing of 15 cm and plant to plant spacing of 7 .5 cm to get optimum yield. The labour requirement in manual transplanting of onion seedlings is as high as 100-120 man-day/ha as 8.9 lakh seedlings per ha are to be transplanted [7].

Seed flow through a planter is dependent on size, shape, sphericity, density and angle of repose of seeds. In addition, the impact of seeds on the internal components of the planter is influenced by the coefficient of restitution of seeds on various impinging surfaces. Therefore, there is a necessity to find out the optimum design parameters of a planter by determining the relevant physical properties of three disparate kinds of crop seeds [3]. [5] determined physical properties such as density, diameters, mass, shape factor, specific gravity, surface area and volume of sweet onions. Although the physical and biometric properties of the crop affects the design parameters of the planter but there is no precise information available on engineering properties of onion crop relevant to design of onion planter.

Due to high labor intensive works and higher wage rate the onion cultivation is discouraged by farmers day by day and hence, area also being reduced in Madhya Pradesh. To overcome such circumstances there is an urgent need to mechanize the planting techniques for the farmers. The present study is carried out to find essential engineering properties of onion bulblets for development of metering device for onion bulblets planter.

MATERIAL AND METHODS

Present study was conducted research farm of Department of Farm Machinery and Power Engineering, College of Agricultural Engineering, J.N.K.V.V., Jabalpur Madhya Pradesh situated between 220 21'and 240 8' N latitude and 780 21'and 800 58' E longitude at an altitude of 411.78 m above mean sea level. In this study variety Agrifound Dark Red of onion bulblets was selected. Various engineering properties of onion bulblet like physical properties, moisture content, Bulk density, angle of repose,

rolling angle etc. were observed. There are three replications were taken for each property. The grading of raw sample was done manually according to the physical appearance (shape and size) of the onion bulblets and three groups of whole sample were finalized as small size sample, medium size sampleand large size sample.The dimensions were measured at average 74.00 per cent moisture content (w.b.) of onion bulblet.

Physical properties of onion bulblets. The physical properties such as length, width, volume, weight, geometric mean diameter, angle of repose, and sphericity are necessary to design a machine used for handling of materials. Therefore, systematic study was done for these properties of onion bulblets with appropriate methods.

Equatorial (D_e) and Polar (D_p) diameter. There are two categories of onion bulblet diameter: polar diameter and equatorial diameter. Polar diameter is the distance between the onion crown and the point of root (bud) attachment to the onion bulblet. Equatorial diameter is the maximum width of the onion in a plane perpendicular to the polar diameter. The equatorial (D_e), and polar diameter (D_p), and thickness (T), of 15 bulblets from each onion bulblet sample were measured with a vernier caliper (least count 0.01 mm).

Average equatorial (D_e) and polar (P_e) diameter were calculated with following relationship [2].

$$D_e = \frac{\sum_{i=1}^{n} D_{ei}}{n};\ D_p = \frac{\sum_{i=1}^{n} P_{ei}}{n};\ T = \frac{\sum_{i=1}^{n} T_i}{n} \quad (1)$$

Geometric mean diameter (D_{gm}). The geometric mean diameter (D_p) was calculated by using the following relationship [2].

$$D_{gm} = \left(D_e D_p T\right)^{1/3} \quad (2)$$

Sphericity (ϕ). Sphericity defines the ratio of the diameter of a sphere of the same volume as that of the particle and the diameter of the smallest circumscribing sphere or generally the largest diameter of the particle [6]. This parameter shows the shape character of cloves relative to the sphere having the same volume.

$$Sphericity = \sqrt{\frac{Volume\ of\ the\ particle}{volume\ of\ circumdcribed\ sphere}} = \frac{\left(D_e D_p T\right)^{1/3}}{L} \quad (3)$$

Shape factor. The shape factor of any granular material is mainly required in designing machinery that utilize their sliding or rolling action for movement by gravity.

Shape factor is defined as the ratio of the equatorial diameter to the polar diameter. A spherical shaped onion bulblet had a shape factor equal to one. Oblate onion bulblet had a shape factor greater had one, and prolate onion bulblet had a shape factor less than one. The shape factor was calculated by using the following relationship [3].

$$Shape\ factor = \frac{Equatorial\ diameter(D_e)}{Polar\ diameter(D_p)} \quad (4)$$

If: $\text{Shape Factor (Fc)} < 1 ; \Rightarrow Oblate$

$\text{Shape Factor (Fc)} = 1 ; \Rightarrow \text{Spherical}$

And: $\text{Shape Factor(Fc)} > 1 ; \Rightarrow prolate$

Unit weight. To obtain the unit weight of a single bulblet, 15 onion bulblets were taken from each onion bulblets sample. Each onion bulblet was weighed one by one by using electronic balance of least count up to 0.01g.

Moisture content. Moisture content was determined on weight basis (w.b.). To determine the moisture content of sample, the onion bulblets were cut in thin slices of 1-2 mm. A 20 g sample of slices was weighted on an electronic balance to a precision of 0.01g, was oven dried to constant weight at 60 ± 2^0C [1].

$$\mathrm{M.C.(w.b.)} = \frac{W_w - W_d}{W_w} \text{ X } 100 \quad (5)$$

Bulk density. Bulk density is an important characteristic for design of seed box. Bulk density of onion bulblet sample was calculated by placing the sample of bulblets in a round cylinder of known volume (Core cutter, volume 1020.5 cm^3) without compaction, and then weighed. The bulk density was calculated as the ratio of weight and volume due to sample. Each sample size used for measuring bulk density and the average was calculated. The sample was weighed by using electronic balance with least count of 1.0 g. Bulk density was calculated by using the relationship as [5].

$$b_d = \frac{W_t}{L \text{ x } \left(\pi d^2/4\right)} \quad (6)$$

Angle of repose. The angle of repose is the angle between the base and the slope of the cone formed vertical fall of the granular material on a horizontal plane. It is an important characteristic in designing seed box [6].

Rolling angle. To determine the rolling angle, the onion bulblet to be tested was kept at the center of the tilting top drafting table (horizontal platform) in most stable position (on their base), then by tilting the platform/table top at minimum speed, the platform inclined until the onion bulblets begins to roll. At this position, the angle of inclination of platform/table top was noted. This was the value of rolling angle for that onion bulblet. There were 15 onion bulblets randomly selected for each sample size [2].

Statistical analysis. The statistical analysis of various parameters like equatorial diameter, polar diameter, geometric mean diameter, Sphericity, Shape factor, Unit weight, Moisture content, Bulk density, angle of repose and rolling angle was done on the basis of standard deviation (SD) and coefficient of variance (CV) at five percent level of significant.

RESULTS AND DISCUSSIONS

Physical properties of bulblet sample. Table1 shows the physical characteristics of onion bulblets of small, medium and large size sample used in laboratory and field evaluation tests of the metering device

Small size sample. The polar diameter range was found to be 21.1 to 25.5 mm with the average diameter of 23.62 mm. The SD and coefficient of variance were calculated to be 1.55 and 5.8 % respectively. Similarly equatorial diameter varied from 10.0 to 14.5 mm with average of 13.2 mm. The SD and coefficient of variance were calculated to be 1.31 cm and 6.2 %, respectively. Geometric mean diameter and sphericity were found to be 15.58 and 0.66 on average of 10 onion bulblets. The SD of geometric mean diameter and sphericity were found to be 1.31 and 0.03, respectively. The coefficient of variance for geometric mean diameter and sphericity was observed to be 5.6 and 3.2, respectively. The shape factor range from 0.47 to 0.62 with 0.56 mean value .The mean of shape factor was less than one so that onion bulblets of small size bulblets were oblate in shape. By using these data the shape of cup was taken as elliptical. The dimensions were measured at average 74.00 per cent moisture content (w.b.) of onion bulblet.

Medium size sample. The polar diameter range was found to be 26.1 to 30.0 mm with the average value of 27.90 mm. The SD and coefficient of variance were calculated to be 1.32 and 5.8 %, respectively. Similarly equatorial diameter varies from 15.1 mm to 23.4 mm with average of 19.54 mm. The SD and coefficient of variance were calculated to be 3.15 cm and 6.2 %, respectively. The geometric mean diameter and sphericity were found to be 0.76 and 0.70 on average of 10 onion bulblets. The SD of geometric mean diameter and sphericity was found to be 0.06 and 3.2, respectively. The coefficient of variance for geometric mean diameter and sphericity was observed to be 3.2 and 9.6 %, respectively. The shape factor ranges from 0.58 to 0.79 with 0.70 mean. The mean of shape factor was less than one so that medium size onion bulblets were oblate in shape. By using these data the shape of cup was taken as elliptical. The dimensions were measured at average 74.00 % moisture content (w.b.) of onion bulblets.

Large size sample *Medium size sample* *Small size sample*

Figure 1. Onion bulblets samples

Table 1. Physical properties of onion bulblet sample

Particulars		*Polar diameter, (mm)*	*Equatorial diameter, (mm)*	*Unit weight, (g)*	*Geometric mean diameter (mm)*	*Sphericity*	*Shape factor*
Small	*Range*	*21.1- 25.5*	*10.0-14.5*	*1.20-2.57*	*14.93-17.85*	*0.59-0.64*	*0.47-0.62*
	Mean	*23.30*	*12.25*	*1.89*	*16.39*	*0.62*	*0.55*
	SD	*1.55*	*1.31*	*0.51*	*1.31*	*0.03*	*0.04*
	CV(%)	*5.8*	*6.2*	*28.6*	*5.6*	*3.2*	*4.7*
Medium	*Range*	*26.1- 30.0*	*15.1-23.4*	*3.06- 4.45*	*16.98-25.32*	*0.73-0.87*	*0.58-0.79*
	Mean	*28.05*	*19.25*	*3.76*	*21.15*	*0.80*	*0.69*
	SD	*1.32*	*3.15*	*0.53*	*0.06*	*0.08*	*0.08*
	CV(%)	*5.8*	*6.2*	*28.4*	*3.2*	*9.6*	*9.6*
Large	*Range*	*30.2- 35.0*	*24.8-30.0*	*5.01- 6.49*	*25.63-30.51*	*0.85-0.97*	*0.8-1.0*
	Mean	*32.60*	*27.40*	*5.75*	*28.07*	*0.91*	*0.90*
	SD	*1.51*	*1.71*	*0.55*	*1.39*	*0.04*	*0.05*
	CV(%)	*6.00*	*6.00*	*28.00*	*5.60*	*3.20*	*6.00*

Large size sample. The polar diameter range was found to be 32.2 mm to 35.0 mm with the average value of 31.58 mm. The SD and coefficient of variance was calculated to be 1.51 and 6.0 % respectively. Similarly equatorial diameter varies from 24.8 to 30.0 mm with average of 28.71 mm. The SD and coefficient of variance was calculated to be 1.71 cm and 6.0 % respectively. The geometric mean diameter and sphericity were found

to be 21.30 mm and 0.70 on average of 10 onion bulblets. The SD of geometric mean diameter and sphericity was found to be 1.39 and 0.04 respectively. The coefficient of variation for geometric mean diameter and sphericity was observed to be 5.6% and 3.2% respectively. The shape factor ranges from 0.8 to 1.0 with 0.70 mean value .The mean of shape factor (0.91) was approximately equal to one so that onion bulblets of large size sample were spherical in shape. By using these data the shape of cup was taken as round. The dimensions were measured at average 74.00 % moisture content (w.b.) of onion bulblet.

Bulk density of onion bulblets. Bulk density of onion bulblets sample was shown in fig.1. The bulk density of small, medium and large size bulblet sample were 607.82, 664.47 and 685.60 kg/m^3 respectively. Average weight of sample was found to be 666.01g and the bulk density obtained 652.63 kg/m^3. The bulk density varies from 607.82 to 685.60 kg/m^3. It was observed that the bulk density of bulblets is increases with increase in bulblet size.

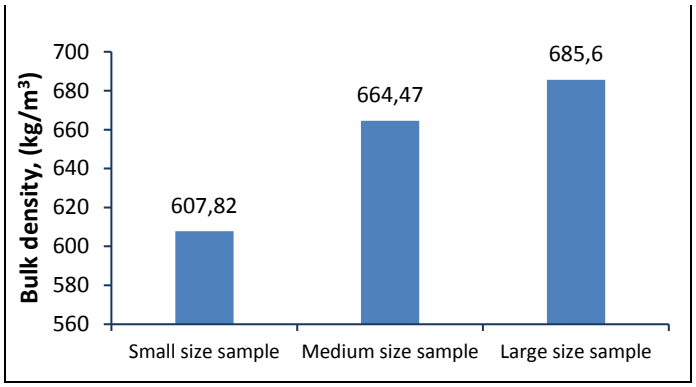

Figure 2. Bulk density of onion bulblets

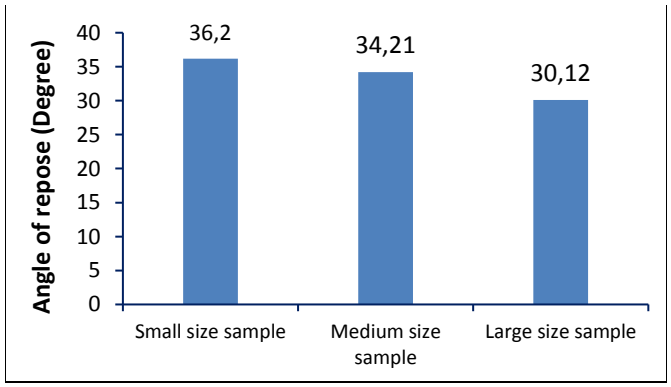

Figure 3. Rolling angle of onion bulblets

Angle of repose. Angle of repose for onion bulblets sample was shown in Fig.3. The angle of repose for three graded samples were found 36.2^0, 34.21^0 and 30.12^0 for small, medium and large samples respectively, with standard variation of 3.10 and 9.25 % coefficient of variance. The results revealed that as size of bulblet is increases the angle of repose decreased.

Table 2. Rolling angle of onion bulblets sample

Particulars	*Small*	*Medium*	*Large*
Range	*9.7^0-10.5^0*	*9.9^0-10.6^0*	*10.1^0-10.7^0*
Mean	*10.21^0*	*10.25^0*	*10.45^0*
SD	*0.24*	*0.26*	*0.17*
CV (%)	*2.37*	*2.53*	*1.64*

Rolling angle. Rolling angle of onion bulblets were shown in Tab. 2. The rolling angle of small, medium and large size bulblet were 607.82, 664.47 and 685.60 kg/m^3 respectively. The value of rolling angle for small, medium and large size bulblet sample ranges from 9.7^0-10.5^0, 9.9^0-10.6^0 and 10.1^0-10.7^0 were observed respectively. On an average rolling angle for small, medium and large size bulblet 10.21^0, 10.25^0 and 10.45^0 was observed respectively. The results revealed that rolling angle was increased with onion bulblet size as per [2].

CONCLUSIONS

This work focuses on some engineering properties of onion bulblets such as equatorial and polar diameters, geometric mean diameter, Sphericity, Shape factor, unit weight, moisture content, bulk density, angle of repose and rolling angle etc. The following conclusions could be made

1. The polar diameter and equatorial diameter of onion bulblets of small size onion bulblets sample were found to be 23.62 mm and 13.2 mm, respectively on average of 10 bulblets at 74.00 % moisture content. The unit weight of onion bulblets was calculated to be 1.87 g with a CV of 28.60 %. The shape factor and geometric diameter were found as 1.31 and 0.04, respectively.
2. The small and medium size bulblets were oblate whereas, the large size sample was spherical in shape.
3. The maximum rolling angle was10.45^0 for large size sample bulblets.
4. The polar diameter and equatorial diameter of onion bulblets of medium size onion bulblets sample were found to be 27.90 mm and 19.54 mm, respectively on average of 10 bulblets at 74.00 % moisture content. The unit weight onion bulblet was calculated to be 3.91 g with a CV of 28.4 %. The shape factor and geometric diameter were found as 0.08 and 0.06 respectively.
5. The polar diameter and equatorial diameter of onion bulblets of large size onion bulblets sample were found to be 31.58 mm and 28.71 mm, respectively on average of 10 bulblets at 74.00 % moisture content. The unit weight of an onion bulblet was calculated to be 5.70 g with a CV of 28.00 %. The shape factor and geometric diameter were as 0.05 and 1.39 respectively.
6. The bulk density of the onion bulblets varies from 607.82-685.60 kg/m^3 and the mean angle of repose was found to be 33.51^0.

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ODREĐIVANJE TEHNIČKIH SVOJSTAVA ZA RAZVOJ MERNOG UREĐAJA SADILICE LUKA

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Sažetak: Tehnička svojstva crnog luka su određena radi razvoja mernog uređaja za sadilicu luka. Sirovi uzorci su bili podeljeni u 3 grupe: mali, srednji i krupni. Osobine su: polarni i ekvatorijalni prečnik, težina, sferičnost, factor oblika i rasuta gustina. Uglovi mirovanja za male, srednje i velike veličine uzorka su 36.200, 34.210 i 33.510, a vrednosti ugla kotrljanja su bili 10.21^0, 10.25^0 i 10.45^0 za male, srednje i velike uzorke veličine respektivno. Vrednosti faktora oblika su bili 0.56, 0.70 i 0,91 za male, srednje i velike uzorke, respektivno.

Ključne reči*:glavice luka, ugao polaganja, factor oblika, ugao kotrljanja*

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MANAGEMENT OF THE MANAGEMENT OF AGRICULTURAL ENTERPRISES USING METHODS OF COMPARISON OF AGRICULTURAL MACHINERY IN THE BUSINESS BOOKS

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Abstract: Operation management among others can be based on the use of specific methods. The authors emphasize the importance of the method of comparison of agricultural techniques and in the books of the company. The true for evaluation and observation of agricultural techniques and equipment as a whole is essential to determine its value. One of the more reliable methods is and method validation equipment by comparison. The advantage of the comparison is evident, as is includes the value of equipment at a given time with the real market, where the minimum deviation. The results in a better and truer way show the value of agricultural equipment, which is also the basis for the introduction of such results in the books of the company. The aim is to highlight the importance of applying new methods of business, such as those shown method of comparison to a more realistic value of the equipment of enterprises, which should serve as the basis for the introduction of so obtained values in the books of the company. The research results are still applicable in large numbers, primarily medium and large agricultural enterprises in the Republic of Serbia, but also more broadly.

Keywords: *evaluation, comparison of agricultural equipment, business books.*

INTRODUCTION

Control is a technique of management, or the use of different methods of administration, to obtain the best possible result. Comparison of the evaluation is a relatively new method in the sense of expressing the real value of the equipment. As in this paper, the authors observe agriculture, it is about observing the prevailing agricultural enterprises that conduct and use a comparison of agricultural equipment in the normal course of business. An increasing number of studies will have to focus its multidisciplinary approach [1], and this approach can speed up the application and results of business [2], [3], primarily in agriculture.

In addition, it should be noted that the valuation of property companies [4], [5] [6], in our work, it is the observation and evaluation of agricultural equipment and machinery is extremely important, because it is a true and fair presentation of the value of assets can make a valid business decision, by the management. This essentially implements the basic principles of management [7], [8], especially in large companies [9]. The

consequence of such an approach substantially facilitates other activities such as auditing within the company, as well as external [10], the overall harmonization of financial reporting [11], [12], [13]. In a word spoken to the responsible management based on socio-economic management of the company. The authors draw attention to the problem in question, from the point of observation of agricultural enterprises. All these activities essentially means facilitating management especially in the case of regular external audits of the companies that are obliged to exercise the same [14], [15], [16] in accordance with applicable regulations of the state [17], [18] in which the company business and management controls them.

The basis for the introduction of the method of comparison of agricultural equipment and mechanization is based on the premise that properly value the company's assets managed by the management, based on respect for the uniform and universal accounting and financial principles deriving from the International Accounting Standards and International Financial Reporting Standards adopted by the most important institutions in this areas such as: FASAB (Financial Accounting Standards Board) and IASB (International Accounting Standards Board).

MATERIAL AND METHODS

The use and the use of methods of valuation of agricultural equipment and mechanization of agricultural enterprises, as well as methods of comparison in order to get the real value of those technologies in the coming years will become more important. The reasons for this are the existence of the use of these international accounting standards as tools in the hands of every agile management.

The value of agricultural equipment companies, to see what is properly used in its ordinary course of business, shall at all times have expressed their true value, which is close to the true market value, and that has to be introduced and expressed in the accounts. The first objective of such activities undertaken by management is to arrive at a value that is close to market value, which means that if the company wants to sell equipment that operates with its value being less oscillation around the market price. The second objective of this management is to comply with the legislation of the country in which they operate agricultural enterprises.

The method of comparison of agricultural equipment means testing and data collection must be relevant, statistically analyzed and presented to management that brings further decisions about what they will do with the data that are obtained by comparison of agricultural equipment. The survey was conducted in the last quarter of 2015 years in the territory of the Republic of Serbia and in. All results obtained by the authors are presented in national currency.

Besides using the data that had to satisfy three areas in the real business of the company as follows,

- the application of accounting policies in companies,
- the treatment of certain parts of the assets of the company,
- as well as testing grounds for the introduction of new asset valuation method.

On this basis, the authors can present the experience that they have acquired and the essence presented in this paper.

RESULTS AND DISCUSSION

Show the results of work by the authors came to this work presented through two whole. In the first part the authors present their basic research covered by the SWOT analysis, where the four main sections of the analysis provide the basic displays that most businesses need with a great deal of respect to be applied in practical terms of

business. At the same time the same serves as the basis for multiple observation of the general impact on the valuation of agricultural equipment in enterprises and the introduction of so obtained values in the books.

*SWOT analysis in the context of the assessment of equipment.*In the more general observation of the authors started from the general assumption that show the basic advantages and disadvantages of applying any valuation of agricultural equipment by the company, as well as the opportunities that assessment can provide the management company, taking into account the real major threat. I display is given in Table 1.

Table 1. SWOT analysis of the agricultural enterprise

ADVANTAGES	*DISADVANTAGES*
- Real time status value of agricultural equipment and agricultural machinery, *- The ability to determine the real market status of equipment regardless of the number of working hours of use of agricultural equipment and other limited factors,* *- Determining the value of which may significantly differ from the value that is in the books of the company, which is the basis for the proper evaluation and the introduction of newly created value in the current business books-spot*	*- Application of estimates requires the engagement of professional people who are often most companies do not come to their company, which increases the costs of engaging third parties,* *- A small number of manufacturers of certain specific equipment which increases the potential error in the valuation of agricultural equipment,* *- Difficulties in the evaluation of older equipment*
OPPORTUNITIES	*THREATS*
- Compliance with the accounting policy of the company, *- Compliance with International Accounting Standards in intervals that are consistent with the accounting policy of the company,* *- Empowering beliefs about the value of agricultural equipment*	*- The possibility of acquiring the wrong picture of the value of agricultural equipment due to miscalculations or not taking sufficient number of comparative assessment,* *- The inability to arrive at a similar comparative,* *- Non-compliance of technical parameters in assessing primarily older equipment and others.*

Source: Author's calculations

These authors are given full access to the observation and the pros and cons of applying the method comparisons on real business enterprises. In addition to the perceived benefits of using the method of valuation of agricultural equipment, it is necessary to take into account the threats that are important limiting factors in creating the accounting policies of companies, as they may distort the true picture of the value of the equipment. Any omissions that may arise when assessing the value of condition subsequent actions at company level as a correction of the financial statements. All those points to the possible subsequent costs that could have come if management fails before the introduction of valued resources and equipment in the accounting records of the company.

Comparisons and farm equipment on the example of IMT 542 from the standpoint of value, year. The authors have made a case IMT 542 from the standpoint of evaluating and taking into account the criteria values in the relevant market in the Republic of Serbia. Only evaluation and display values which were obtained by the authors from the value point of the day 26.11.2015. The authors demonstrated in Table 2. The results are given in EUR, so that the wider scientific community had the right image evaluation IMT 542 in the Republic of Serbia. In this part of the paper the authors present their

required values IMT 542, the expected values for which will be held sales and years of the production of the said tractors.

Table 2. Display market and the expected value IMT 542, as well as the production of the same

Ordinal number	*The requested value of the relevant market in the Republic of Serbia*	*Expected value by which to achieve purchase*	*The year of production*
1	*2300*	*2100*	*1984*
2	*2600*	*2400*	*1985*
3	*2900*	*2700*	*1986*
4	*3000*	*2800*	*1987*
5	*4200*	*4000*	*1991*

Source: Author's calculations

Creating a general model comparisons. To show the importance of the general model comparisons, the authors created a model that can serve as a general model in which followed the weight or the equipment in the selected company that exists in the market of Novi Sad in 1962 and which belongs to a group of enterprises in the field of agricultural activities. The authors note that this is a medium size company. Accordingly, the weight of the farm equipment that is observed with the 4 basic characteristics and has a real value expressed in books, while comparatives equipment that is used for comparison, and the data for each comparative authors have obtained from the market that are considered relevant, or from the territory the Republic of Serbia.

In this part of the paper the authors have pointed out that in addition to the previously highlighted the important parameters in modeling should be included and others such as: of maintenance of equipment, functionality of equipment, improvement of equipment, and can include more detailed analysis of some parameters.

See the model comparison IMT 542 as a general model; the authors have given in Tab. 3.

Table 3. Overall comparisons of model validation and application in tractor IMT 542

Characteristics of the equipment	*Ponder (%)*	*Komprarativ 1 (%)*	*Komprarativ 2 (%)*	*Komprarativ 3 (%)*
Age	*25*	*21*	*22*	*19*
Of maintenance	*20*	*25*	*21*	*19*
functionality	*50*	*40*	*38*	*35*
enhancements	*5*	*5*	*3*	*2*
The basis of comparison	*100*	*91*	*84*	*75*

Source: Author's calculations

Already on the basis of the display table 3 it is clear that variations and comparative weights may be substantial and could have a significant impact on the change in value of agricultural equipment to be introduced in the books. In view of the possible model variations are seen in the range of 25-9%, which significantly changes the actual picture of the value of assets, and evaluating IMT 542 equipment, which served as a realistic representation of the model variations evaluation of the said tractors.

On the basis of the results clearly shows that there is significant variation in the management of value IMT 542 in the books and the value that is obtained on the market by comparison. The average deviation is 16.6%, and only if we take into accounts three comparisons. On a number of comparisons to get somewhat different results, but they would not differ significantly from the results presented. Therefore the case study on the example of IMT 542 clearly indicates that the application of the method of comparison is very desirable and expedient, because very often in the books of value equipment is not

water current in relation to the market value and the need to perform more frequent synchronization, as the recommended the International Accounting Standards, in particular IAS-16s.

The author draws attention to the professional community needs to include more parameters for comparison in order to get expedient and convincing data that are close to fair value or market value.

CONCLUSIONS

Valuation of agricultural equipment will come in the coming years more and more to the fore. Therefore, management must find a way to apply other methods to a more realistic value in its accounts. This is necessary because only fair presentation means the first step of proper business management. Assessing the value of the equipment can be done in several ways. In this paper, the authors show the comparative method that can be used, before only in medium and large businesses. The authors pointed out that apart from the age of tractors it is necessary to include other factors such as: improvement of equipment, maintenance, and other functionality. These are not the only factors. Each of the responsible managers may include some and other factors that it deems relevant. Second's vital importance, authors have pointed out in this paper and the appreciation of the importance of the introduction of the results of the assessment of business books, as well as the importance of comparison IMT 542, because deviations can be considerable.

The method presented in comparison to the overall valuing can give good results, because unlike the other method involves several fields of observation in the evaluation of tractors and other agricultural machines.

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UPRAVLJANJE MENADŽMENTA POLJOPRIVREDNOG PREDUZEĆA UZ KORIŠĆENJE METODA KOMPARACIJE POLJOPRIVREDNE MEHANIZACIJE U POSLOVNIM KNJIGAMA

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Sažetak: U ovom radu je istaknut značaj metode komparacije poljoprivredne tehnike u poslovnim knjigama preduzeća. Naime za istinito vrednovanje i posmatranje poljoprivredne tehnike i opreme u celini je bitno utvrditi njenu vrednost. Jedno od pouzdanijih metoda je i vrednovanje opreme pomoću komparacija. Prednost komparacija je očigledna, jer se obuhvata vrednost opreme u određenom trenutku sa realnog tržišta, gde su odstupanja minimalna. Dobijeni rezultati na bolji i istinitiji način prikazuju vrednost poljoprivredne opreme, što je ujedno i osnova za uvođenje tako dobijenih rezultata u poslovne knjige preduzeća. Cilj rada je isticanje značaja primene novih metoda u poslovanju, poput ove prikazane metode komparacije. Rezultati istraživanja su primenjlivi u velikom broju, pre svega srednjih i velikih poljoprivrednih preduzeća u Republici Srbiji, ali i šire posmatrano.

Ključne reči: *vrednovanje, komparacija poljooprivredne opreme, poslovne knjige.*

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MODELING THE MOISTURE DEPENDENT THERMAL PROPERTIES OF MULTIPLIER ONION (*Allium Cepa* L. var *Aggregatum*)

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Abstract: The thermal properties of multiplier onion namely thermal conductivity, thermal diffusivity and specific heat were determined in the moisture range of 80.87 to 88.84 % w.b. Thermal conductivity was determined using a line heat source transient heat transfer method whereas the thermal diffusivity was determined by Dickerson method using the thermal diffusivity probe. The thermal conductivity and specific heat of onion increased whereas the thermal diffusivity decreased with increase in moisture content. The thermal conductivity, thermal diffusivity and specific heat of onion ranged from 0.17 ± 0.01 to 0.53 ± 0.03 W/mK, 4.32 x 10^{-7} ± 0.58 to 2.01 x 10^{-7} ± 0.11 m^2/s and 1.01 to 5.75 J/kg.K, respectively. Mathematical modeling was done using the linear regression analysis to predict the specific heat of onions. Among the different models developed, the empirical equation which involved the thermal diffusivity and moisture content predicted the specific heat of onion with a R^2 of 0.974.

Key words*: multiplier onion, thermal conductivity, thermal diffusivity, specific heat, moisture content, modeling*

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INTRODUCTION

Onion is one of the agricultural commodities that have an important role in human diet. Onions (*allium cepa* L.) are highly valued as flavouring agents. *Aggregatum* onion (*Allium Cepa* L.Var. *aggregatum*) also known as multiplier onion, is one of the important types of onion grown extensively in southern states of India. Tamil Nadu onions are very sensitive to weather conditions. If not cured properly after harvest the storage life of onions would be reduced due to physiological loss in weight, decay, fungal and mould growth, rotting and sprouting. This in turn leads to a heavy loss to farmers. Curing is being traditionally followed by heaping the onion for a period of two weeks by spreading on the floor in shade or under field conditions. However this traditional curing is not possible during monsoon periods. Artificial curing plays a vital role under such situations. The knowledge on the thermal properties of onion bulbs is required not only to quantify the thermal processes but also to design the artificial curing and storage systems. Specific heat, thermal conductivity and thermal diffusivity are the most important moisture-dependent thermal properties.

The thermal properties namely thermal conductivity, thermal diffusivity and specific heat capacity each can be measured by several well-established methods. The two methods for measuring thermal conductivity include the steady and line heat source transient state heat transfer methods. This line heat source transient heat transfer method has frequently been used in recent years for the determination of thermal conductivity of maize and cowpea [3], banana [2] and berberies fruit [10].

The thermal diffusivity can be measured by either a thermal conductivity probe or a thermal diffusivity tube. The thermal diffusivity probe and tube method had been followed for determining the thermal diffusivity of sweet potato [13] and egusi melon [6], respectively. Specific heat is an important thermal property used in heat transfer and energy balance calculations [7]. There are several methods to measure specific heat of foods. In the method of mixtures the error is caused by heat of solution of soluble matter in the sample. This method has been used by researchers such as barley [5] and for straw mushroom [19]. Another method is the differential scaning calorimeter (DSC) which is more precise but more expensive and requires specific sample preparation.The specific heat can also be calculated using the experimental thermal conductivity and thermal diffusivity data.

Thermal property data of various biological materials have been reviewed and reported so far, however, data pertaining to the thermal properties of multiplier onion bulbs are very limited and scanty. Hence the study was undertaken to determine the thermal properties of multiplier onion with the objective to determine the thermal conductivity, specific heat capacity and thermal diffusivity of multiplier onion as a function of moisture content and to develop a linear regression model to determine the specific heat as a function of thermal diffusivity, thermal conductivity and moisture content.

MATERIAL AND METHODS

Raw material. Field harvested onions (CO-4) were used for all the experiments in this study. The onion harvested during 2014 growing season at the farmer's field of

Ottanchatram, Tamil Nadu, India was procured for the study. The onions were cleaned manually wherein all foreign matter such as dust, dirt, stones, and chaff as well as immature and spoiled onions were removed. Moisture content of the onion was determined using AOAC 1996 method [1]. Onion samples were dried using hot air oven at 105°C until a constant weight was obtained. The average moisture content was found to be 84.46 % w.b. Onion samples were dried and conditioned to obtain different moisture contents ranging between 80.87 and 88.84 % w.b. A cabinet drier (M/s. Macneill and Magor limited, Calcutta, India) was used for decreasing the moisture content of the onions. To condition the onion samples to higher moisture content, a calculated quantity of distilled water was added [5].The sample was equilibrated at room temperature (30±2°C) before conducting different tests [15].

Thermal conductivity. Thermal conductivity was determined using the transient state heat transfer method (Fig. 1).The test cylinder made of 26 gauge aluminium of size 201 mm x 460 mm contained the onion samples. The probe inside the test cylinder consisted of a 26 gauge thick constantan heating wire of resistivity 15.4 ohms per meter length. The heating wire was insulated with teflon tape and encased in a 6 mm diameter brass tube. The heating wire was attached at lower end of the brass tube. A copper- constantan thermocouple was inserted into the brass tube up to 13 cm from the top, for the measurement of sample temperature, for calculating its thermal conductivity. Power for heating the wire was supplied by a variable DC power supply unit of 1 to 30V and 0 to 2A capacity. A 35 ohms rheostat was used to control the current flow in the circuit. A 5A ammeter was used to measure the current in the circuit.

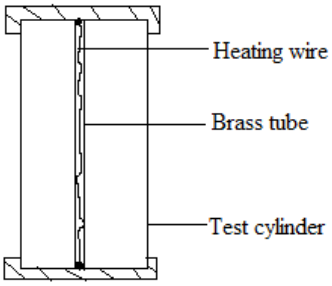

Figure1. Schematic arrangement of test apparatus for measuring thermal conductivity

The thermal conductivity of the sample was calculated using the following Eq. 1:

$$K = [q / 4\pi(T_2 - T_1]\ln[(Q_2 - Q_0)/(Q_1 - Q_0)] \quad (1)$$

Where, q = Heat supplied per unit length of thermal conductivity probe (W/m), T_1 = Temperature of thermocouple at time Q1 (°C), T_2 = Temperature of thermocouple at time Q_2 (°C), Q_0 = Time correction for finite diameter of probe (s), Q_1 and Q_2 = Time corresponding to temperatures T_1 and T_2 (s).

Thermal diffusivity. The thermal diffusivity was determined using Dickerson apparatus (Fig.2). A cylindrical probe of 56 mm diameter and 243 mm long made of copper and coated with chromium was used to hold the sample. The teflon lid was used to cover the top and bottom of the cylinder in order to ensure only radial heat transfer. Through the centre of the top lid, a thermocouple junction was inserted and placed at the

centre of the probe. Another thermocouple was placed at outside surface of the probe. After filling the onion samples in the probe, the top lid with thermocouple was positioned. The probe was placed within the agitated water bath and the rise in temperature was noted by both thermocouples until the difference between these became constant. The thermal diffusivity of the sample was calculated using the Eq. 2.

The thermal diffusivity was determined using the following equation:

$$D = \frac{AR^2}{4(T_1 - T_2)} \tag{2}$$

Where, D- Thermal diffusivity (m^2/s), R- Inner radius of cylinder (m), T_1- Surface temperature of probe(° C), T_2- Centre temperature of onions (° C), A- Slope.

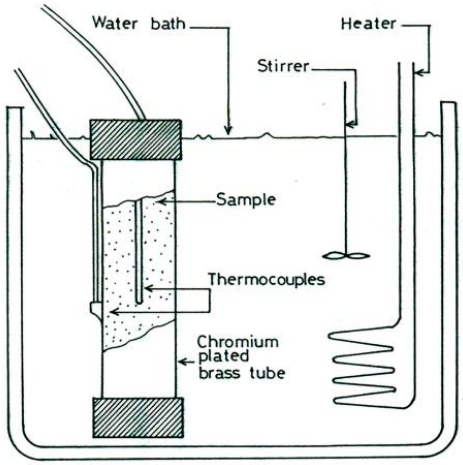

Figure 2. Schematic arrangement of test apparatus for measuring thermal diffusivity

Specific heat. From the thermal diffusivity and thermal conductivity values, the specific heat of onion was calculated using the Eq. 3:

$$C_p = \frac{K}{\rho\sigma} \tag{3}$$

Where, C_p = Specific heat (J/kg.K), K = Thermal conductivity (W/mK), ρ = Bulk density, (kg/m^3), σ = Thermal diffusivity (m^2/s).

The experiments were conducted in triplicate and was analyzed using Analysis of Variance (ANOVA) followed by Least Significant Difference (LSD) Test using the AGRESS software version 7.01. The Factorial Completely Randomized Design (FCRD) was followed for the ANOVA estimation.

Modeling the specific heat. The specific heat (C_p) was modeled using single or multiple linear regression analysis as proposed for modeling the mass of banana fruit [16]. Thermal diffusivity (σ), thermal conductivity (K) and moisture content (m) data were analyzed to predict the specific heat of onion bulbs. Five linear regression equations were predicted. In all the equations A and B indicate the coefficient of independent variable and C is the constant. Modeling was done using SPSS 16.0 and the

suitability of the model was selected based on the highest R^2 (Coefficient of determination) and lowest standard error of estimate.

RESULTS AND DISCUSSION

The thermal properties namely thermal conductivity, thermal diffusivity and specific heat have been determined at a moisture range of 80.87 to 88.84 % w.b. and are represented in Tab. 1. As the moisture content increased, the thermal conductivity of onion bulbs significantly increased ($P<0.1$) from 0.17 ± 0.01 to 0.53 ± 0.03 W/mK. This is due to the decreasing porosity of the onions with increasing moisture content. Water and air have the highest and lowest thermal conductivity respectively, as compared to dry agricultural materials. Therefore the moisture content increased the volume of the pores reduced resulting in a higher thermal conductivity. The positive linear dependence of thermal conductivity on moisture content has also been reported for ginger [8], banana [16], cowpea and maize [3].

As the moisture content increased from 80.87 to 88.84 % w.b., the thermal diffusivity of onion bulbs significantly decreased ($P<0.1$) from 4.32 x 10^{-7} ± 0.58 to 2.01 x 10^{-7} ± 0.11 m^2/s. The decrease in thermal diffusivity with moisture content has also been reported for pea nut pod and kernel [4], egusi Melon [6] and rice flour [9].

The specific heat of onion bulbs varied from 1.01 to 5.75 J/Kg. K at moisture content ranging between 80.87 to 88.84 % w.b. The specific heat increased significantly ($P<0.1$) with increasing moisture content. The increased specific heat with increasing moisture content is due to the high specific heat of water compared to the dry material, and the tendency of water to occupy the air-filled pores at a faster rate [13]. The result was in line with fermented ground cassava [12] and pistachio nuts [17].

Table 1. Effect of moisture content on the thermal properties of onion bulb

Thermal properties	*Moisture content, % w.b.*	*Mean*	*S.D*	*S.E*
Thermal conductivity (W/mk)	*80.87*	*0.17 d*	*0.01*	*0.005*
	82.91	*0.23 c*	*0.02*	*0.011*
	85.25	*0.43 b*	*0.06*	*0.034*
	88.84	*0.53 a*	*0.03*	*0.017*
Thermal diffusivity (m^2/s)	*80.87*	*4.32 a x 10^{-7}*	*0.58*	*0.334*
	82.91	*3.49 b x 10-7*	*0.45*	*0.259*
	85.25	*3.16 b x 10^{-7}*	*0.2*	*0.115*
	88.84	*2.01 c x 10^{-7}*	*0.11*	*0.063*
Specific heat (J/kg.K)	*80.87*	*1.01 d*	*0.87*	*0.502*
	82.91	*1.56 c*	*0.55*	*0.317*
	85.25	*3.02 b*	*0.12*	*0.069*
	88.84	*5.75 a*	*0.95*	*0.548*

All data represent the mean± standard deviation (S.D). a-d letters indicate the statistical difference in same columns ($P<0.05$)

The results of the mathematical modeling *viz.* model coefficient, coefficient of determination R^2, Adjusted R^2 and the Error Sum of Estimate (ESE) for the thermal conductivity, thermal diffusivity and specific heat are provided in Tab. 2, 3 and 4,

respectively. Fig. 3-5 represents the fit of various models to the thermal properties as a function of moisture content. The best model was selected based on the highest R^2 and lower ESE values.

Table 2. Models predicting thermal conductivity as a function of moisture content

S.No.	Model	Equations	R^2	Adjusted R^2	ESE
1.	Linear	$K= -3.713+ 0.048* m$	0.948	0.923	0.047
2.	Logarithmic	$K= -17.749+ 4.078 \ln m$	0.951	0.926	0.046
3.	Quadratic	$K= -18.142+ 0.388 *m - 0.002 * m^2$	0.958	0.873	0.060
4.	Power	$K= 1.154E -25 * m^{12.679}$	0.927	0.891	0.175
5.	Exponential	$K= Exp (1.057E-06 + 0.149 *m)$	0.922	0.883	0.182

From Tab. 2, the logarithmic model with a $R^2 = 0.951$, adjusted $R^2 = 0.926$ and ESE = 0.046 was found to be the best fit model for prediction of thermal conductivity as a function of moisture content

The linear, logarithmic and quadratic models predicted the thermal diffusivity of the onions with a $R^2 = 0.979$ and ESE = 0.000 as represented in Tab. 3. Any one of the above models could be considered for determining the relationship between moisture content and thermal diffusivity of onions.

Table 3. Models predicting thermal diffusivity as a function of moisture content

S.No.	Model	Equations	R^2	Adjusted R^2	ESE
1.	Linear	$\sigma = 2.663E-06- 2.76E-08* m$	0.979	0.968	0.000
2.	Logarithmic	$\sigma = -1.075E-05-2.35E-06 * m$	0.979	0.968	0.000
3.	Quadratic	$\sigma = 3.323E-06 - 4.32E-08* m - 9.165E-01* m^2$	0.979	0.936	0.000
4.	Power	$\sigma = 4.444E-08 * m^{-7.866}$	0.966	0.949	0.073
5.	Exponential	$\sigma = Exp (0.001 - 0.093* m)$	0.969	0.954	0.069

Table 4. Models predicting specific heat as a function of moisture content

S.No.	Model	Equations	R^2	Adjusted R^2	ESE
1.	Linear	$C_p = -48.766+ 0.611* m$	0.971	0.957	0.441
2.	Logarithmic	$C_p = -1.075E-05 - 2.350E-06* m$	0.966	0.950	0.476
3.	Quadratic	$C_p = 260.058 - 6.669* m - 0 .043* m^2$	0.998	0.995	0.154
4.	Power	$C_p = 1.154E-36 * m^{18.842}$	0.993	0.989	0.078
5.	Exponential	$C_p = Exp (1.671E-08 + 0.222* m)$	0.991	0.987	0.086

Table 5. Specific heat models of multiplier onion

S.No.	Equations	A	B	R^2	C	ESE
1.	$C_p = \sigma A+ C$	-2.143 E07	-	0.936	9.790	0.657
2.	$C_p = K A+ C$	11.984	-	0.907	-1.239	0.791
3.	$C_p = \sigma A+ m B+C$	7.674 E06	0.823	0.974	-69.198	0.595
4.	$C_p = KA+ m B+C$	1.778	0.696	0.972	-55.369	0.612
5.	$C_p = \sigma A+ K B+C$	-1.32 E07	4.811	0.955	5.587	0.782

The power law model is adjudged as the best fit model to predict the relationship between specific heat and moisture content with a $R^2 = 0.993$, adjusted $R^2 = 0.989$ and ESE = 0.078 as shown in Tab. 4.

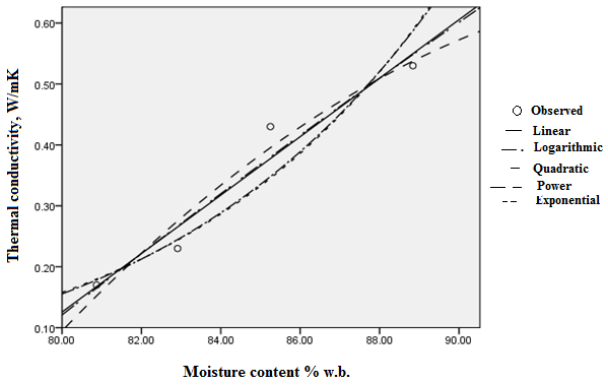

Figure 3. Models predicting the effect of moisture content on the thermal conductivity of onion bulbs

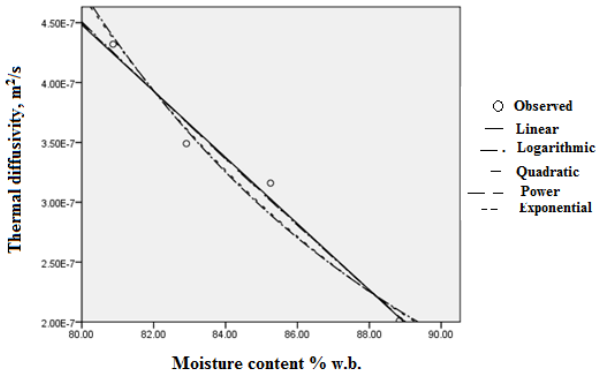

Figure 4. Models predicting the effect of moisture content on the thermal diffusivity of onion bulbs

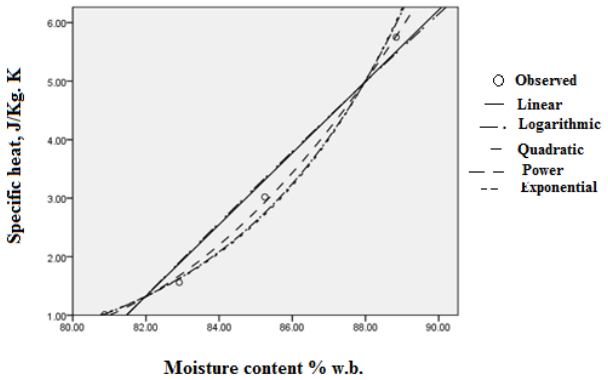

Figure 5. Models predicting the effect of moisture content on the specific heat of onion bulbs

Among the five regression models presented in Tab. 5, the following equation (6) predicted the specific heat with a $R^2 = 0.974$ and ESE = 0.595 and found to be the best fit model for calculating the specific heat of multiplier onion as a function of moisture content and thermal diffusivity.

$$C_p = 7.674E06(\sigma) + 0.823(m) - 69.198 \quad (4)$$

CONCLUSIONS

The thermal properties determined were used for modeling the specific heat of multiplier onion as a function of moisture content. The best fit model predicting the thermal properties was chosen based on coefficient of determination (R^2) and Error Sum of Estimate (ESE). The recommended linear regression model describing the specific heat of multiplier onion is:

$$C_p = \sigma K_1 + mK_2 + C$$

The thermal property data determined for the multiplier onions would be useful for designing an artificial curing and storage system and in the prediction of energy requirement involved in heat transfer operations.

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MODELIRANJE TERMIČKIH KARAKTERISTIKA LUKA (*Allium Cepa* L. var *Aggregatum*) U ZAVISNOSTI OD SADRŽAJA VLAGE

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Sažetak: Termalne osobine luka, kao što su: toplotna provodljivost, toplotna difuzija i specifična toplota su određivane u opsegu vlage od 80.87 do 88.84%. Toplotna provodljivost je određena metodom prolaznog prenosa toplote dok je toplotna difuzija određena Dickerson metodom, korišćenjem toplotne difuzione sonde. Toplotna provodljivost i specifična toplota crnog luka porasle su dok je toplotna difuzija smanjena sa povećanjem sadržaja vlage. Toplotna provodljivost, toplotna difuzija i specifična toplota crnog luka u rasponu od 0,17 ± 0,01 na 0,53 ± 0,03 V/mK , 4.32 h 10-7 ± 0,58 do 2,01 k 10-7 ± 0,11 m^2/s i 1,01 do 5,75 J/kg.K , redom. Matematičko modeliranje je urađeno pomoću linearne regresione analize predviđene specifične toplote luka. Među

različitim razvijenim modelima, empirijska jednačina koja uključuje toplotnu difuziju i sadržaj vlage predvidela je specificnu toplotu crnog luka sa R^2 od 0,974 .

***Ključne reči**: luk, toplotna provodljivost, termička difuzija, specifična toplota, sadržaj vlage, modeliranje*

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COMPARATIVE FIELD AND ECONOMIC EVALUATION OF BALER FOR BALING PADDY STRAW

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Abstract: A study was conducted to evaluate performance of paddy straw baler on loose paddy straw (system A), after stubble shaver operation (system B) and after stubble shaver along with rake operation (system C). The number of bales per ha and density of bales increased with increase in feed rate of paddy straw from 1.12 to 4.22 $t.h^{-1}$ and highest feed rate was observed when stubble shaver and rake were operated prior to baler (system C). The field capacities of system A, B and C were 0.35, 0.40 and 0.53 $ha.h^{-1}$ and the number of bales per ha varied from 126-149, 266-292, 298-332 respectively. The mean fuel consumption for system A, B and C were 5.0, 10.0 and 12.0 $l.h^{-1}$ respectively. The mean percentage increase in density of bales, number of bales and productivity of baler were more for system C as compared with system A and B. The benefit cost ratio was found to be maximum for system C as 1.16:1 and for systems B and A were 1.06:1 and 0.85:1 respectively. The net savings per ha were Rs. 471.05 and 1537.59 with system B and C respectively.

Key words*: baler, density, feed rate, field capacity, paddy straw, rake, stubble shaver*

INTRODUCTION

Burning of paddy residue left in field leads to release of soot particles and smoke causing human health problems, emission of greenhouse gases such as carbon dioxide, methane and nitrous oxide causing global warming, loss of plant nutrients such as N, P, K and S and useful micro organisms, adverse impacts on soil properties and wastage of valuable C and energy rich residues. If rice straw is not burnt or incorporated in the soil then baling may provide an attractive, economical and environmentally safe option. There are wide usages of the straw in paper mills for cardboard manufacturing, for packaging the materials, for mushroom cultivation, for burning in boilers, for animal feed in drought regions etc. So baling the straw and compacting it into small (120-135$kg.m^{-3}$), transportable size and shapes is also economical and safe for environment.

The baling facility in the field helps in saving the straw from weather calamities, makes handling and transportation easier, facilitates its easy and safe storage and maintains its quality. A baler is used to compress a cut and raked crop such as hay and straw into bales and bind them with twine. Rice occupied 2.808 million hectares with total production of 11.236 million tones during 2009-2010 in Punjab. The average grain yield of rice was 4.01 $t.ha^{-1}$ and average yield in terms of paddy was 6.033 t/ha [1]. The total yield of paddy straw in combine-harvested field is about 12.5 $t.ha^{-1}$ and the yield of standing stubbles and loose straw are about 7 $t.ha^{-1}$ and 5.5 $t.ha^{-1}$, respectively [4].

[3] mentioned that the two types of balers in popular use for baling straw and other fibrous materials are rectangular and round balers. They added that the bale density of the straw is affected by the type of material being baled, its moisture content at time of baling, and the resistance provided by convergence of the bale chamber. The bale density increased by increasing baler feeding rate and the moisture content of the materials being baled [2]. He also found that the optimum bale density was obtained by using the plunger-type field baler (36 x 46 cm bale chamber) at the feeding rates ranged from 4.2 to 6.0 $t.h^{-1}$ and the moisture content of rice straw bales ranged from 15 to 20%. [5] conducted the experiments on straw baler for its field performance and its economic evaluation in combine-harvested paddy field. The area of each experiment was 0.4 ha. The field capacity of the baler was 0.26 $ha.h^{-1}$ in combine-harvested paddy field and 0.36 $ha.h^{-1}$ in the field where stubble shaver was operated before baling. The size of bale varied from 80 x 45 x 45 cm to 90 x 45 x 45 cm, and accordingly the weight of bales varied from 18 to 28 kg. The number of bales formed was 205 in combine-harvested paddy field and 425 in stubble-shaved paddy field. Economics of the straw baler revealed that the cost of baling in stubble-shaved field was Rs. 2276.00/ha and the cost of transporting the bales was Rs. 4400.00/ha. The total cost of baling in stubble-shaved field including transportation of bales was Rs. 6676.00/ha. Very high transportation cost is the only reason due to which the machine is not gaining popularity. The total income from sale of straw was Rs. 5865/ha. [6] conducted economic investigation of field vegetable production introduced by using the production technology of tomato and they mentioned that costs of crop transport depend on the distance between the place of harvest and the processing company. Transport costs can be as high as production costs. The paddy straw burning issue can be resolved using baler machine and can earn profit to farmers also. Keeping the need in view, a technological approach was assessed to evaluate economic/comparative performance of baler for paddy straw in-situ condition and also after stubble shaver and rake machine operation in paddy straw field.

MATERIAL AND METHODS

The baling operation is a mechanical process, require three tractor-driven machines for cutting, lining, gathering and making bales. First stubble shaver is operated to harvest the stubbles from base level and then lining operation is perform by the rake machine after that gathering and bale formation is completed by the baler. The paddy straw moisture content varied from 15-25 % (wet basis) and straw load varied from 5.5-10.0 $t.ha^{-1}$ during field experiments. Tractor of 50 HP was used for present study. The stubble shaver, rake and baler machine used for baling purpose are described below:

Stubble Shaver Machine. The stubble shaver is used for cutting of standing paddy stubbles. It consists of two blades mounted on a vertical shaft and blades are covered with frame from four sides and top. The shaft is rotated by tractor PTO shaft through a gear box. It cuts standing paddy stubbles in the field (Fig. 1). It was operated in 2^{nd} low gear and between 1500-1700 engine rpm depending upon paddy straw load.

Figure 1. A view of stubble shaver machine

Figure 2. A view of rake machine

Rotary Rake Machine.The paddy stubbles cut by stubble shaver alongwith loose straw can be gathered in a narrow width using tractor operated rake. The rotary rake of 180 kg weight was used for the present study having raking width 2.6 m and spreading width 2.9 m (Fig. 2). The tractor requirement of rake machine is 35 HP. The function of rake is to collect the cut and loose paddy straw from field and makes a windrow of narrower section thereby provides dense straw input for baler machine. It was operated in 3rd low gear and between 1500-1700 engine rpm depending upon paddy straw load.

Table 1. Specifications of rectangular baler

S. No.	*Specifications*	*Dimensions*
1.	*Type*	*Rectangular*
2.	*Bale Size*	
	ss section b. Length	*x 46 cm b. 31 to 132 cm*
3.	*Flow-Action® Feeding System*	
	e	*Six feeder tines on a moving finger bar*
	ve	*Chain; sealed ball bearings*
4.	*Feed Opening*	*1826 cm²*
5.	*Plunger*	
	roke length b. Speed (540 rpm)	*2 cm b. 79 SPM*
6.	*Tying Mechanisms*	
	e b. Protection c. Capacity	*otter b. Shear bolt c. 04 Balls*
7.	*Dimensions*	
	ght (max.)b. Width c. Length	*a.146 cm b. 275 cm c. 610 cm*
8.	*Weight (approximate)*	*1399 kg*
9.	*Recommended Transport Speed*	*32 km/h*
10.	*Tractor Requirement**	*35 hp*
	**Tractor weight must be greater than baler weight;*	

Rectangular Baler Machine. The performance evaluation of rectangular baler was done in the present study. The baler specifications are given in Tab.1. In this baler there was provision for controlling degree of compaction and bale density. The metering device for varying the bale length is also given.

The main drive on the baler was hypoid geared in which crown wheel and pinions engage each other spirally. The advantage of this was that the contact area of the gear teeth was larger than with normal gear meshing and this contributes to durability and reliable power flow. In front of the transmission there was a large flywheel that absorbs the ram forces and ensures the smooth running characteristics of the baler. In present study baler was operated in 2nd low gear between 1500-1800 engine rpm depending upon paddy straw load.

Field Operations. The baler was operated in three field conditions of paddy straw. In first condition, the baler machine was directly operated in the combine harvested

paddy field without operation of any other machine. The baler machine was operated on paddy straw (standing + loose) after its sun drying for few days. In this condition, baler picks only loose paddy straw from the field. In the second condition, stubble shaver was operated in combine harvested paddy field for harvesting of standing stubbles. Thereafter the baler was operated in this field. In the third condition the stubble shaver was operated in combine harvested paddy field and then rake was operated in the same field. After the operation of stubble shaver and rake, baler was operated in the paddy straw field (Fig. 3). Under all of these three conditions parameters like number of bales, forward speed, operating width, field capacity, fuel consumption etc. were observed and recorded.

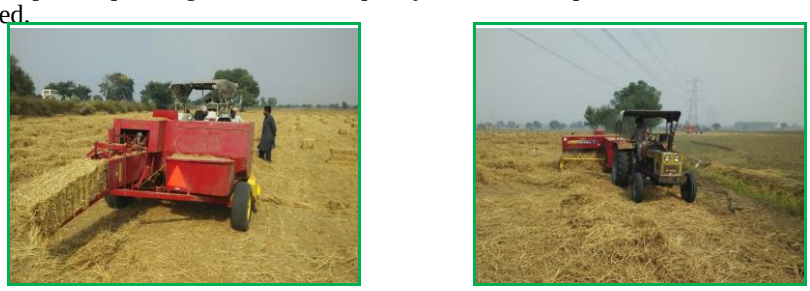

Figure 3. Views of baler machine in stubble shaver + rake operated field and only stubble shaver operated field.

RESULTS AND DISCUSSION

After operating baler for paddy straw in-situ condition and after stubble shaver and rake machine operation, field parameters for evaluating baler machine were recorded. The baler machine parameters like forward speed, feed rate, operating width, field capacity, number of bales per hectare, volume and weight of bale (for density calculation), fuel consumption were recorded and are shown in Table 3. The average length, width and height of bales varied between 87-92 cm, 46-52 cm and 30-36 cm and weight of bales varied between 18-30 kg during different field experiments. The field capacities of system A, B and C were 0.35, 0.40 and 0.53 $ha.h^{-1}$ respectively and the effect was significant at 5 % level of significance. The number of bales per ha varied from 126-149, 266-292, 298-332 respectively for system A, B and C respectively and the effect was significant at 5 % level of significance. Density of bales was highest for baler operation after stubble shaver and rake operation on paddy straw and the effect was significant at 5 % level of significance. The mean fuel consumption for system A, B and C were 5.0, 10.0 and 12.0 $l.h^{-1}$ respectively under varying straw load conditions. The mean % increase in density of bales, number of bales and productivity of baler were more for system C as compared with system A and B. It is clear from Tab. 2 that the number of bales was more when baler was operated after the operation of stubble shaver and rake. The effect of feed rate on field capacity and fuel consumption of different systems and on number of bales and density of bales is shown in Fig. 4.

Table 2. Field evaluation of baler with three different systems

Particulars	*Baler (for loose paddy straw only) [A]*	*Stubble shaver + Baler [B]*	*Stubble shaver + Rake + Baler [C]*	*CD (5%)*
Mean forward speed, $km.h^{-1}$	*1.52*	*2.42*	*3.18*	-----

Mean feed rate of paddy straw, t.h^{-1}	*1.12*	*2.85*	*4.22*	*0.1281*
Mean Tractor Engine rpm	*1200*	*1200*	*1200*	-----
Mean operating width, m	*1.65*	*1.65*	*1.65*	-----
Field capacity of baler (mean), ha.h^{-1}	*0.33-0.37 (0.35)*	*0.39-0.42 (0.40)*	*0.52-0.55 (0.53)*	*0.03052*
Number of bales per ha (mean)	*126-149 (140)*	*266-292 (277)*	*298-332 (320)*	*30.4377*
Density of bale (mean), kg/m^3	*154.20-157.10 (155.77)*	*184.10-188.05 (185.72)*	*205.00-207.35 (205.97)*	*3.2504*
Fuel consumption (mean), l.h^{-1}	*4.50-5.50 (5.00)*	*9.00-11.75 (10.00)*	*10.75-13.25 (12.00)*	*2.3432*
Comparison between various systems	*Mean % increase in number of bales*	*Mean % increase in productivity of baler*	*Mean % increase in density of bales*	----
With system B in comparison to system A	*49.46 %*	*12.50 %*	*16.13 %*	-----
With system C in comparison to system A	*56.25 %*	*33.96 %*	*24.37 %*	----
With system C in comparison to system B	*13.44 %*	*24.53 %*	*9.83 %*	----

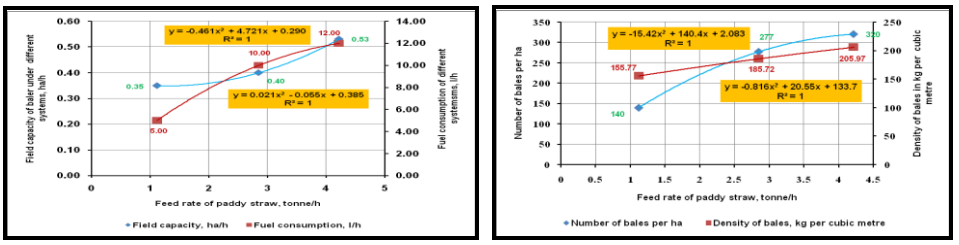

Figure 4. Effect of feed rate on field capacity of baler and fuel consumption of different systems and on number of bales and density of bales

The various regression equations between feed rate, field capacity of baler, fuel consumption, number and density of bales were obtained from these graphs and are as follows:

The equation for field capacity (ha.h^{-1}) of baler as a function of feed rate of paddy straw (t.h^{-1}) is

$$y = 0.021x^2-0.055x+0.385 \quad (1)$$

The equation for fuel consumption of different systems (l.h^{-1}) as a function of feed rate of paddy straw (t.h^{-1}) is

$$y = -0.461x^2+4.721x+0.290 \quad (2)$$

The equation for number of bales per ha as a function of feed rate of paddy straw (t.h^{-1}) is

$$y = -15.42x^2+140.4x+2.083 \quad (3)$$

The equation for density of bales (kg.m^{-3}) as a function of feed rate of paddy straw (t.h^{-1}) is

$$y = -0.816x^2+20.55x+133.7 \quad (4)$$

It is clear from Fig. 4 that with increase in feed rate from 1.12-4.22 $t.h^{-1}$ numbers of bales increased from 140-320 and density of bales increased from 155.77-205.97 $kg.m^{-3}$ and effect of three different systems was found to be significant on feed rate.

Economic Evaluation of Baler Machine (with and without rake machine). There are different types of uses of baled paddy such as packaging purpose, power unit, compost etc. Few power units running on paddy straw are also established in Punjab, detail of which is given in Tab. 3. So there is a good scope for baler in future in context to all these uses. However for economics calculation of three systems i.e. with and without rake was calculated based on fixed costs, variable costs and average returns from sale of baled paddy straw and are shown in Tab. 4. The benefit cost ratio was found to be maximum for system C as 1.16:1 and for systems B and A was 1.06:1 and 0.85:1 respectively (Fig. 5). The system C was found to be most economical of three systems. The system A can be used by farmer alongwith happy seeder machine. As after collection of loose straw from combine harvested paddy field, happy seeder machine can be used for direct sowing of wheat in standing stubbles.

Table 3. Detail of Use of Paddy straw by different Power Generation Plants in Punjab

S. No.	*Thermal power plant which uses paddy straw*	*Capacity (Mega Watt (MW))*	*Rate of straw per tonne (rate cut by 10 % if moisture exceeds 10 %)*	*Paddy straw Area (ha) Covered in year 2013*	*Paddy straw quantity recovered (Tonne)*
1.	*M/s Malwa Power Ltd., village Gulabewala, Muktsar*	*6*	*1200*	*8800*	*55000*
2.	*M/s Punjab Biomass Power Pvt. Limited, Vill. Khokhar Khurd, Mansa,*	*10*	*1200*	*2,000*	*12,500*
3.	*M/s Punjab Biomass Power Pvt. Ltd. , Village Ghannaur, Patiala*	*12*	*1500*	*8000*	*50,000*

Table 4. Economic returns from baler with and without rake system

Particulars	*Tractor*	*Baler*	*Stubble shaver*	*Rake*
New Cost, P	*5,00000*	*5,00000 (After 50% subsidy)*	*40,000*	*1,00,000*
Salvage Value, S (10 % of P)	*50,000*	*50,000*	*4000*	*10000*
Life, L (Years)	*10 years*	*10 years*	*10 years*	*10 years*
Avg. Use/Year (h)	*1000*	*400*	*400*	*400*
Annual fixed charges				
Depreciation, Rs./yr = (P-S)/L	*45,000*	*45,000*	*3600*	*9000*
Rate of interest , i (%)	*12*	*12*	*12*	*12*
*Interest cost, Rs/yr = (P+S/2)*i*	*33,000*	*33,000*	*2640*	*6600*
Taxes, Insurance and shelter Rs./yr, 2% of P	*10,000*	*10,000*	*800*	*2000*
Total fixed cost, Rs/year	*88,000*	*88,000*	*7040*	*17,600*
Total fixed cost, Rs/h	*88*	*220*	*17.6*	*44*
Variable cost				
Repair & maintenance = 5% of P/Avg.	*25*	*62.5*	*5*	*12.5*

use /yr, Rs./h				
Mean Fuel consumption, l.h^{-1}	------	*5*	*4*	*3*
Fuel cost, Rs/h (Fuel cons. x rate@Rs.57per litre)	------	*260*	*208*	*156*
Cost of lubricants, (Rs./h) = 20 % of fuel cost		*52*	*42*	*32*
Labor cost, Rs//h	*20*	*30*	*20*	*20*
Total variable cost, Rs./h	------	*404.50*	*279.00*	*220.50*
Fixed +Variable, Rs./h	*133.00*	*624.50*	*296.60*	*264.50*
Total cost of using implement with tractor Rs./h	----	*757.50*	*429.60*	*397.50*
		System A	*System B*	*System C*
Cost of operation, Rs./h	----	*757.50*	*1187.10*	*1584.60*
Field capacity, ha.h^{-1}	----	*0.35*	*0.40*	*0.53*
Cost of opertation, Rs./ha (Fixed and variable)	----	*2164.28*	*2967.75*	*2989.81*
Mean number of bales/ha	----	*144.00*	*277.00*	*320.00*
Twine cost, Rs./ha (@Rs. 3.3 per bale)	----	*475.20*	*914.10*	*1056.00*
Transportation cost Rs./ha (@Rs.450/tonne for biomass plant in 30 km radius)	----	*1496.70*	*3116.25*	*4032.00*
Grand Total Cost of operation, Rs./ha	----	*4893.68*	*8185.20*	*9662.41*
Mean Straw recovered, t.ha^{-1}	----	*3.326*	*6.925*	*8.960*
Income from straw sale, Rs./ha (@Rs. 1250/tonne)	----	*4157.50*	*8656.25*	*11200*
Saving, Rs/ha (USD per ha)*		*-736.18 (USD --11.49)*	*+471.05 (USD 7.35)*	*+1537.59 (USD 23.99)*
B:C (Benefit:Cost) Ratio	----	*0.85:1*	*1.06:1*	*1.16:1*

**1 USD = 64.08 Indian rupee*

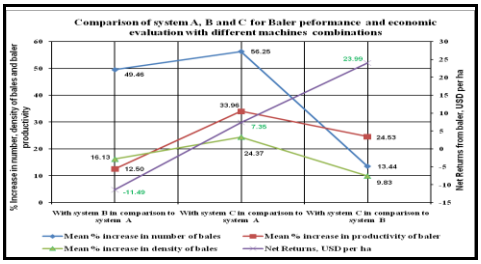

Figure 5. Effect of three different systems on performance of baler

CONCLUSIONS

The field capacities of system A, B and C were 0.35, 0.40 and 0.53 ha.h^{-1} and the number of bales per ha varied from 126-149, 266-292, 298-332 respectively for system A, B and C respectively and the mean fuel consumption for system A, B and C were 5.0, 10.0 and 12.0 l.h^{-1} respectively. The mean percentage increase in density of bales, number of bales and productivity of baler were more for system C as compared with system A and B. The benefit cost ratio was found to be maximum for system C as 1.16:1 and for systems B and A were 1.06:1 and 0.85:1 respectively. The net savings per ha were Rs. 471.05 and 1537.59 with system B and C respectively. The number of bales per

ha and density of bales increased with increase in feed rate of paddy straw from 1.12 to 4.22 $t.h^{-1}$ The numbers of bales were more when baler was operated after stubble shaver and rake and the bales formed were denser as compared to bales formed without operating rake in field. The net returns from baler were more when operated after stubble shaver and rake as compared to other two systems.

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UPOREDNO POLJSKO I EKONOMSKO ISPITIVANJE BALERA ZA BALIRANJE SLAME PIRINČA

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Sažetak: Studija je izvedena radi ocene karakteristika balera slame pirinča. Broj i sabijenost bala se povećala sa povećanjem prinosa slame. Poljski kapacitet i broj bala varirali su u intervalima od 126-149, 266-292, 298-332, redom. Srednja potrošnja goriva za sisteme A, B i C bila je 5.0, 10.0 i 12.0 $l.h^{-1}$, redom. Maksimalan odnos troškova i prihoda bio je kod sistema C i iznosio 1.16:1.

Ključne reči*: baler, gustina, norma, poljski kapacitet, slama pirinča, grablje*

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CFD SIMULATION OF COOLING OF CORIANDER SEED UNDER DIFFERENT MOISTURE CONTENT

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Abstract: CFD simulation of cooling during cryo-grinding of coriander seeds was performing to determine its residence time in conveyer. Coriander seed at different moisture content were simulated and the equations were solved over a defined space and time domain, discredited by computational grids and time steps. Simulation result shows that temperature of coriander seed reduces from 27 to -53ºC in 12 sec. The simulation also accounts the effect of moisture content on temperature distribution and time of cooling. The numerical simulation was further verified through cooling experiments with coriander seed by directly dipping them in liquid nitrogen. Simulation data well matched with experimental results. The chilling rate of seed was found to be time, product-temperature and moisture dependent.

Key words*: CFD simulation, heat transfer, moisture content, spices.*

INTRODUCTION

Computational fluid dynamics (CFD) is a simulation tool, which uses powerful computer and applied mathematics based fluid-flow modelling for the prediction of heat, mass and momentum transfer and optimize design for industrial unit processes [1, 2, 3, 4]. Some design engineers actually use CFD to analyse new systems before deciding which and how many validation tests need to be performed. It also facilitates deep analysis of local effects in a lot of equipment [5, 6] and results in an improved performance, reliability, scale-up, product consistency and higher plant productivity [7].

Recently, the application of CFD simulation has gained immense importance in food processing industry. CFD solutions are being used to develop equipment, optimise and

processing strategies in the food industry and their rate of use has grown exponentially, as evidenced by the steady increase in peer-reviewed journal papers over the years. The many areas within the food industry where CFD has been routinely used to quantify governing physical phenomena include sterilisation [8], mixing [9], drying processes [10], belt dryer [11], vacuum cooling [12], cold store [13], heat and moisture transfer in stored grains [14], Natural Convection Cooling [15], convective heating [16], Natural Ventilation [17], Supercritical Fluid Extraction [18], evaporative cooling [19, 20], to name but a few, with the range of applications being continuously extended. The food and beverage industrial processes are used regularly to enhance quality, safety and shelf life of food stuffs [21] and links between CFD and the processes such as mixing, drying, cooking, sterilisation, chilling and cold storage are profound. Mathematical and numerical simulation have been perform by different researcher on different process like heat load [22], drying [4] and Natural Ventilation [17] etc., but none of the simulation study was focused on cryo-cooling of spice.

Spices are one of the most important constituents of Indian food. They are widely used in households, hotels, restaurants and food processing industries, either used in form of powder or whole to improve the flavour of food. A perfect grinding system of spices must reduce the size of product while maintaining good product quality in terms of favour and colour [23]. But, normal grinding process of size reduction generates heat. The temperature of the product rises in the range of 42°C to 95°C [24] resulting in loss of some volatile flavouring compounds and degradation of quality. It also depends upon the composition, moisture content and the method of grinding. Temperature rise during grinding process can be minimized to some extent by cold air or water circulation around the grinding machine or grinding in to two or more stage, although these techniques proves inefficient in reducing the temperature rise significantly. [23] developed a cryo-grinding system for spice where the spices were cooled before feeding to the grinder by using liquid N_2 (-195.6°C) and the temperature 10 to 30^{o}C below the freezing point of oil is maintained throughout the conveying zone by conveying and same temperature product were feed in to the grinder.

We, thus state that the present study is first study focussing on utilisation of CFD simulation to predict the time of cooling as well as temperature profile during cryo-cooling of spices (Coriander seed). The heat transfer during cryo-cooling process for determination of cooling time and temperature profile of spices with respect to different moisture content has been simulated and will aid in designing and scaling-up the precise system for cryo cooling.

MATERIAL AND METHODS

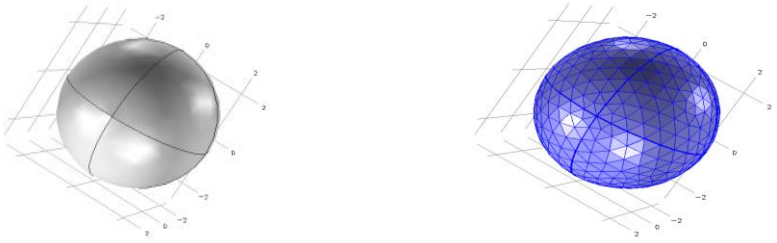
Sample preparation. Coriander seed samples were collected from the local market in Kharagpur and were maintained at different moisture content 8, 10 and 12% (w.b.). The physical and thermal properties of the seed were evaluated for CFD simulation and were previously discussed [25, 26].

Modelling the problem

*Cryo-cooling of spices***.** Cryo-grinding involves grinding the spices at low temperature. During the process, temperature of spices was reduced to a certain level

(i.e. below the solidification point of coriander oil) to reduce the volatile loss. The spices were then transferred to grinder through cooling tunnel or conveyer in presence of liquid nitrogen. The time of Cooling is a deciding factor for travelling time of grain in the conveyer. Most of the heat were removed by liquid nitrogen which converts to gas and maintain the temperature during conveying. Single grains were selected to simulate the cooling process and geometry as described previously in another paper [25].

*The physical model***.** Considering the physical properties at different moisture content [25], spherical geometry (Figure 1) was used for simulation of coriander seed cooling. Liquid nitrogen was injected over the grain during cryo-cooling and hence, in simulation, it was assumed that the grain has been surrounded by cloud of liquid nitrogen. Computer three-dimensional modelling was used to simulate the heat transfer phenomena, the temperature profile and time of cooling. Also, an experimental study was conducted to confirm the results obtained through simulation.



a. *b.*

Figure1: Geometry of coriander seed before (a) and after meshing (b)

*Initial and Boundary conditions***.** The selection of boundary conditions was based on following assumptions:

a. Sphericity of coriander seed was considered as one value.
b. During cooling process, seed is clouded by liquid nitrogen.
c. There is no phase change in liquid nitrogen.
d. No heat loss occurred during the cooling process to surrounding.
e. No heat generation during transportation and handling of spices in conveyer.

The considered boundary conditions as per the chosen product for simulation are as follows:

a) Initial temperature of coriander= 27ºC
b) Initial temperature of liquid nitrogen = -195ºC
c) Time of cooling =12 sec

Additionally, the physical and thermal properties with respect to moisture content were taken from previous study [26].

Solution methodology and governing equations. Heat transfer simulation of spices was done in COMSOL multi-physics software. Following were the steps for modelling –

1. Start COMSOL multi-physics and select model type (1D, 2D, 3D), Next select physics (heat transfer, heat transfer in porous etc.) and select study type (time dependent or stationary).

2. Among different options in tree of model builder, first set unit for geometry and proceed to draw geometry (Figure 1) by clicking 'build it' option to complete the process.
3. Add material and their properties by click on material or select material option according to physics selected. Provide boundary conditions by clicking on selected physics.
4. In next option i.e. mesh, two option sequence type and element size appear. In sequence type physics, controlled mesh and user controlled mesh two options appear. And are set as default. Give size and shape of mesh by clicking on user controlled type. Change mess size to fine, extra fine, finer, coarse, extra course by clicking on element size option.
5. In study option, select time dependent study, and set process parameter, physics and time of study.
6. Under result options, select the kind or form in which we want to express the result.
7. After performing all the setting steps right click on study and click on compute.

In this time dependent study, geometry of sphere was assume as sphere (Figure 1) and fine meshing was done to check the temperature distribution over each node. Boundary conditions were set to simulate the cryo-cooling. The software was used to solve the governing continuity, momentum and energy equations for the defined geometry and associated boundary conditions. The domain was defined in the global co-ordinate frame in which the solver carries out the calculations.

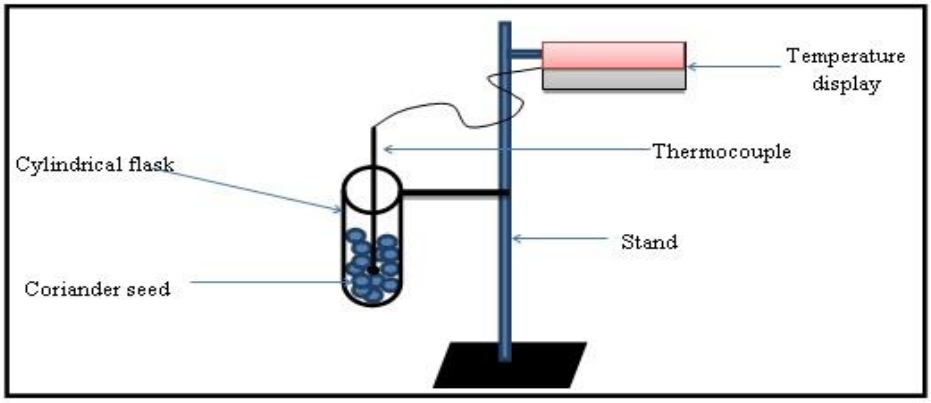


Figure 2. Experimental setup for cooling validation

a) The generalized equations for continuity, momentum and energy are as follows: Continuity equation

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho V) = 0 \tag{1}$$

b) Momentum equation

$$\frac{d\rho V}{dt} + \nabla.(\rho V * V) = \nabla\left(-p\delta + \eta(\nabla V + (\nabla V)')\right) + Sm \tag{2}$$

c) Energy equation

$$\frac{\partial \rho h_t}{\partial t} - \frac{Dp}{Dt} + \nabla.(\rho V h_t) = \nabla.(k \nabla t) + S_E \quad (3)$$

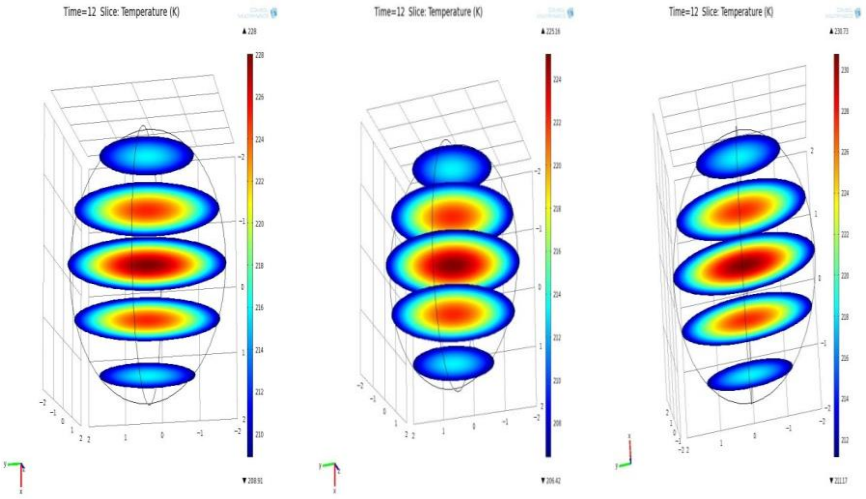
$$S_m = -\rho_{ref}\beta(T - T_{ref})g \quad (4)$$

Where, 'h total' is the specific total enthalpy expressed in terms of temperature and pressure. For the energy equation S_E is taken to be zero as there are no internal sources of energy.

Experimental verification. An experiment was carried out in a laboratory for verification of CFD simulation. Tropical cryo-cooling process was performed by direct dipping the spices in liquid nitrogen. Temperature of coriander seed was measured at time intervals of 2, 4,6,8,10,12 seconds. The experimental setup for temperature measurement is shown in fig 2. Some dipped spice seeds were taken out after certain time at defined time intervals and were filled into the tube or cylindrical flask with thermocouple. The readings of temperatures were noted down from temperature display unit.

RESULT AND DISCUSSION

The predicted temperature distribution within the spherical gain after a chilling time of 12sce can be visualised in Figure 3, which indicates that the temperature of the spice after chilling is higher at the core and decreases from the core to surface. The maximum temperature drop was found in the surface of the spices. In experimental verification we observed that the chilling rate was the highest at beginning of cooling process as the products initial temperature is 27ºC and the product temperature gradually decreased with the time. The chilling rate also decreased gradually with time and temperature of the product towards the end of chilling process.



(i): 8% w.b (ii): 10% w.b (iii): 12% w.b.

Figure3. Temperature profile of coriander seed at different moisture content

Comparison of experimental and simulation results showed better arrangement and relevance between the simulation and experimental data. Average temperature of spice seeds reduced from 27 to – 53ºC in 12 sec which shows little variation with the experimental data. Moisture present in the food grain acted as a critical factor affecting the rate of cooling. It was observed that an increase in moisture content led to a decrease in the cooling rate but increases the cooling time. Moisture present in food grain also affected the heat transfer capacity of food grain. The thermal conductivity of the coriander seed reduced with an increase in moisture content. Besides these, several factors seems to determine the accuracy of simulation. It was assumed that the geometry of spices is a regular sphere, however in reality; the sphericity value for coriander is not one [25]. Also the geometry and e shape varies with the type of grain under study and variation under assumptions may lead to prediction errors. Also, the initial temperature of spice temperature was assumed to be completely uniform in the simulation, which is very difficult to achieve in practice [12].

CONCLUSION

The CFD simulation of the cryogenic cooling of coriander seed well fitted with the data of verification experiments. It was also observed that the seed internal temperature and the chilling rate decreased with the time of cooling process. Also, higher moisture content reduces the spice thermal conductivity. Although, through CFD simulation we were able to select appropriate design values and operation conditions for developing the cryogenic cooling system for coriander seed spice but the assumptions laid for the simulation acts as a constraint in efficient applicability to other spice products. A better or developed version of software predicting the temperature at each point of product and exact geometry of seed may aid better in applying this technique. The CFD simulation model developed will prove very useful in determining design variables for during cryo cooling equipment building when cost is a major constraint factor. To achieve the more accurate result, it is suggested to take account of parameters like heat loss, heat generation during transportation and changes in the cooling media throughout the process.

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CFD SIMULACIJA HLAĐENJA SEMENA KORIJANDERA SA RAZLIČITIM SADRŽAJEM VLAGE

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Sažetak: CFD simulacija za hlađenje tokom zamrznutog mlevenja semena korijandera je izvedena da se odredi vreme zadržavanja u konvejeru. Simulirana su semena korijandera sa različitim sadržajem vlage i jednačine su rešene za definisan prostorni i vremenski domen, diskreditovan računskim mrežama i vremenskim intervalima. Rezultat simulacije pokazuje da temperatura semena korijandera opada od 27 do -53°C za 12 sec. Simulacija takođe uključuje uticaj vlažnosti na distribuciji temperature i vreme hlađenja. Numerička simulacija je dodatno potvrđena eksperimentima naglog hlađenja semena korijandera direktnim potapanjem u tečni azot.

Ključne reči*: CFD simulacija, prenos toplote, sadržaj vlage, začini*

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