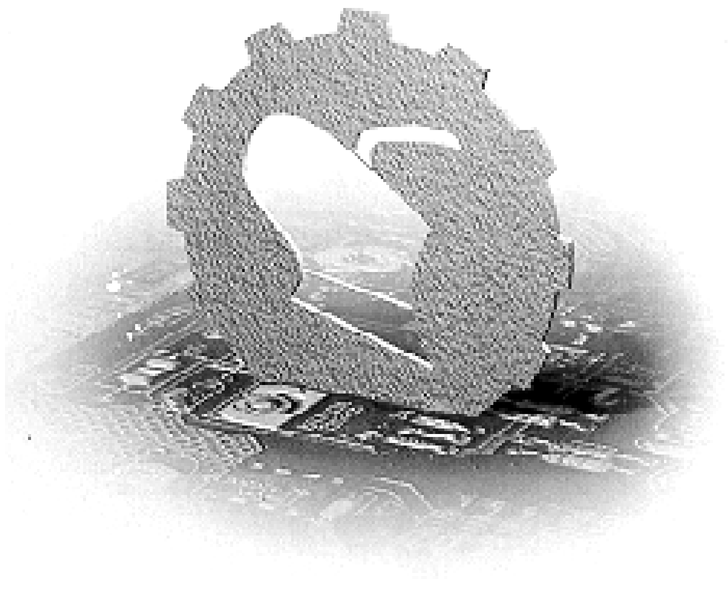
Print ISSN 0554-5587
Online ISSN 2406-1123
UDK 631 (059)

ПОЉОПРИВРЕДНА ТЕХНИКА

AGRICULTURAL ENGINEERING

НАУЧНИ ЧАСОПИС
SCIENTIFIC JOURNAL



УНИВЕРЗИТЕТ У БЕОГРАДУ, ПОЉОПРИВРЕДНИ ФАКУЛТЕТ,
ИНСТИТУТ ЗА ПОЉОПРИВРЕДНУ ТЕХНИКУ
UNIVERSITY OF BELGRADE, FACULTY OF AGRICULTURE,
INSTITUTE OF AGRICULTURAL ENGINEERING

Година XL, Број 4, 2015.
Year XL, No. 4, 2015.

Издавач *(Publisher)*
Универзитет у Београду, Пољопривредни факултет, Институт за пољопривредну технику, Београд-Земун
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AGRIS i SCIndeks

Издавање часописа помогло *(Publication supported by)*

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На основу мишљења Министарства за науку и технологију Републике Србије по решењу бр. 413-00-606/96-01 од 24. 12. 1996. године, часопис Пољопривредна техника је ослобођен плаћања пореза на промет робе на мало.

S A D R Ž A J

C O N T E N T S

Univerzitet u Beogradu Poljoprivredni fakultet Institut za poljoprivrednu tehniku Naučni časopis **POLJOPRIVREDNA TEHNIKA** Godina XL Broj 4, 2015. Strane: 1 - 8	University of Belgrade Faculty of Agriculture Institute of Agricultural Engineering Scientific Journal **AGRICULTURAL ENGINEERING** Year XL No. 4, 2015. pp: 1 - 8

UDK: 626.628

Originalni naučni rad
Original scientific paper

WATER RESOURCES CONSERVATION PLAN FOR RANGAPUR WATERSHED IN MIDDLE KRISHNA BASIN IN RAICHUR DISTRICT OF KARNATAKA USING REMOTE SENSING AND GIS

Mallika Kurdi[1*], Banda Maheshwara Babu[1], Gejjala Venkataravanappa Srinivasa Reddy[1], Basavaraj Shivanagouda Polisgowdar[1], Rajesh Neralikere[2]

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Abstract: The study area Rangapur watershed covers an area of about 2079 ha, is one of the drought prone areas in the middle Krishna Basin in Raichur district of Karnataka. An attempt is made to suggest location priority plan for the sustainable development of the area using GIS and remote sensing techniques. The IRS P6 LISS III imagery was used for the preparation of land use/land cover and hydrogeomorphology maps. Geologically most of the watershed is covered by the rocks of Archean age *i.e.* granite gneiss. The major geomorphic units mapped in the area are shallow weathered pediplain, moderately weathered pediplain and structural valley. Among all, shallow weathered pediplain cover most part of the area. Arc Hydrology model of ArcGIS 10 version was used to propose various soil moisture conservation and water harvesting structures. From the results 22 nala bunds, 34 check dams and 141 boulder checks were suggested at different locations across streams. Thus it is recommended that water harvesting should be given importance to increase the groundwater recharge besides providing supplementary irrigation during rabi season.

Key words*: Check dam, Nala bund, Boulder checks, hydro geomorphology, hand use/land cover, watershed, remote sensing, GIS, water harvesting, groundwater recharge*

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INTRODUCTION

Land and water resources are limited and their wide utilization is imperative, especially for countries like India, where the population pressure is increasingly continuous. These resource development programs are applied generally on watershed basis and thus prioritization is essential for proper planning and management of natural resources for sustainable development [11]. Land use reefer's to man's activity and various uses which are carried on the land, whereas land cover refers to natural vegetation, water bodies, rock/soil, artificial cover and other resulting due to land formations [13]. Watershed deterioration is a common phenomenon in most parts of the world. In addition, availability of land, erratic and uneven distribution of rains, undulating topography, improper resource management, traditional cropping programs and recurrence of droughts having cumulative effect leading to lower productivity and higher risk particularly in resource planning under dry-land farming.

Watershed approach has been the single most important landmark in the direction of bringing in visible benefits in rural areas and attracting people's participation in watershed programs [8]. The basic objective of the study is to increase production and availability of food, fodder and fuel; restore ecological balance. An attempt is made using remote sensing and GIS techniques to propose various water harvesting and soil conservation measures in order to suggest integrated land and water resource development plan for Rangapur watershed in middle Krishna basin in Raichur district of Karnataka.

MATERIAL AND METHODS

The study was taken up in Rangapur watershed having an area of 2079 ha which is located in between the villages of Bevinbenchi and Yadlapur in Raichur district of Karnataka (Fig. 1).

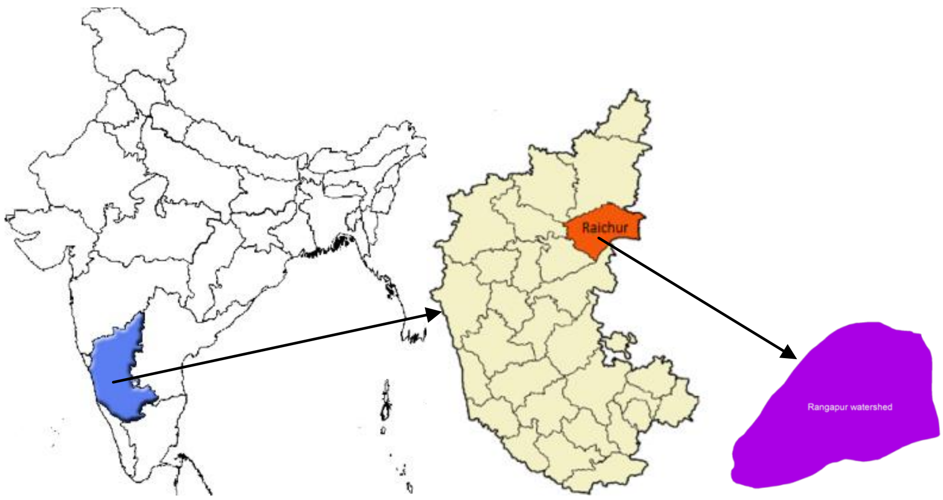

Figure 1. Location map of study area

The study area is situated in the North-Eastern dry zone of Karnataka at 16˚20'20" to 16˚23'5" N latitude and 77˚17'21" to 77˚20'58" E longitude and elevation is from 338 to 382 m above mean sea level (MSL). The Survey of India toposheet 56 H/7 of 1:50,000 scale was used for development of maps and for the analysis of watershed characteristics.

The different maps like watershed base map, drainage map, contour map, DEM (Digital Elevation Model), slope map, aspect map and hydro geomorphology map were prepared from the toposheet and remote sensing image. The land use/land cover classification was done with IRS-P6, LISS III image pertaining to crop season (16^{th} Nov 2011) [14] by using ERDAS 2010 imagine. These thematic maps were calculated using raster calculator in spatial analyst of ArcGIS 10, based on the weightages decided. The formula for this raster calculation is as follows: ((Hydrogeomorphology)·0.2+(Land Use/Land cover)·0.2 + (Soils)·0.1 + (Slope)·0.2 + (Drainage)·0.3).

RESULTS AND DISCUSSION

The study emphasizes on prioritization of watersheds for their development and management on a sustainable basis, based on available natural resources.

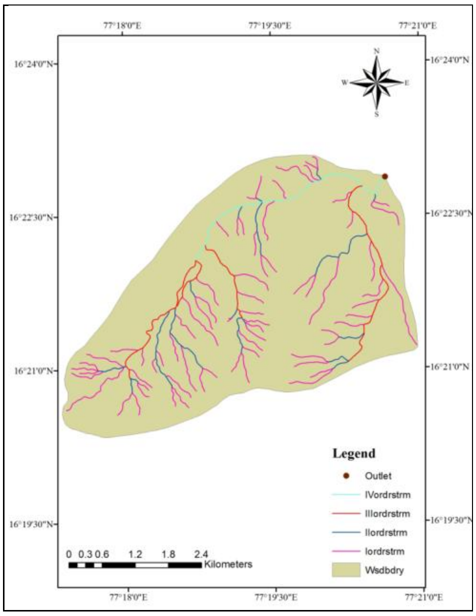

Figure 2. Drainage map of Rangapur watershed

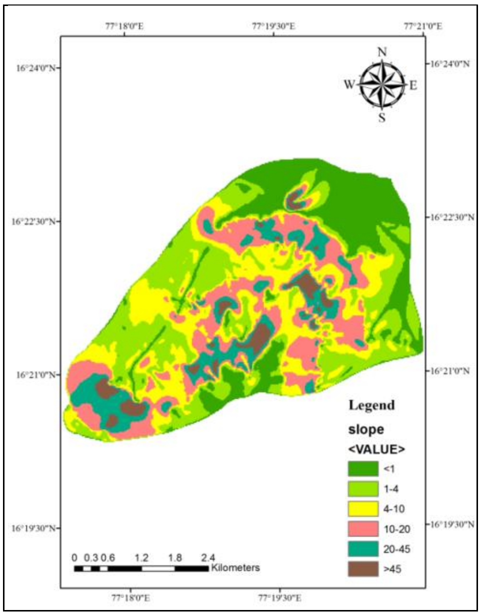

Figure 3. Slope map of Rangapur watershed

The various themes, which include drainage, slope, hydro geomorphology, soil and land use/ land cover were considered for prioritization. These maps were integrated and finally water resources conservation maps were prepared.

Drainage. The drainage map was prepared from the SoI toposheet forms the base map for the preparation of thematic maps related to surface and groundwater. Drainage map includes all the streams, tributaries and small stream channels and depicts flow pattern of drainage lines in the study area (Fig. 2). The lengths of all stream orders were obtained from drainage map using ArcGIS 10 software. The drainage pattern observed in the study area is *dendritic*. The highest stream order is of fourth order.

Slope. Slope is the most important terrain characteristics plays a vital role in hydro geomorphological and runoff processes, soil erosion, infiltration and land use/land cover [1,2]. The slope map was derived using the DEM which was prepared using contour lines and spot elevations from the toposheet [3,4] [6]. About 32.54% of the total study area fell into slope class 1 (< 1%) while 35.98 % of the study area having a slope class of 2 fell in the range of (1 - 4%). In similar way slope classes of 3 (4-10%), 4 (10-20%), 5 (20-45%) and 6 (>45%) were covered an area about 14.22%, 8.76%, 5.29% and 3.21 % (Fig. 3).

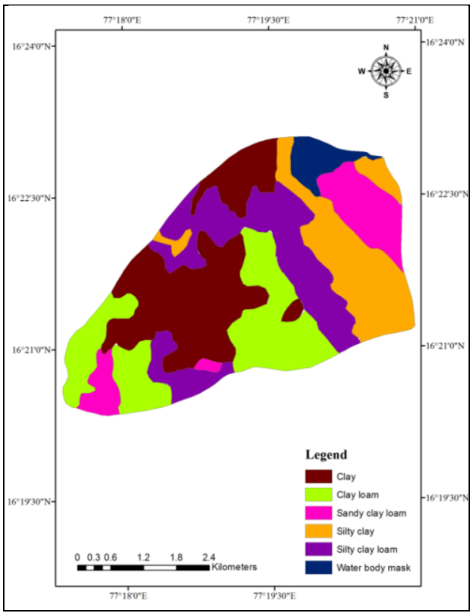

Figure 4. Soil map of Rangapur watershed

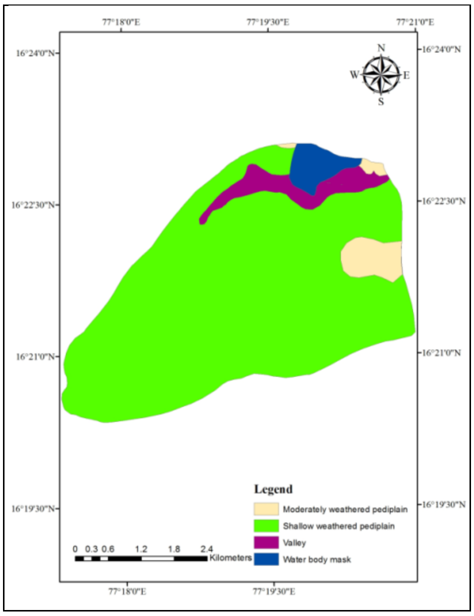

Figure 5. Hydro geomorphology map of Rangapur watershed

Soil. The soils of watershed occur on basaltic and lateritic parent materials and are characterized by different physiographic units [5,7]. Soil mapping has been carried out with the help of satellite imagery and field study to determine the soil texture. In the study area mainly five textural classes were found (Fig. 4). The most of the study area is composed of clayey soils which can erode and transferred by heavy rain and moderately percolated the water in to the ground. The other characteristic features of the soil are silty clay, silty clay loam, clay loam and sandy clay loam were observed in the watershed.

Hydro geomorphology. An integrated approach was adopted using remote sensing and GIS techniques in the study area for evaluation of groundwater potential zones based on the characteristics of geomorphic units together with slope, geology and lineaments. The area has been classified into shallow weathered pediplain, moderately weathered pediplain and valley fill, which were observed in the granite gneiss. They are classified for groundwater prospective zones as valley fills and moderately weathered pediplains forms very good to good; good to moderate and shallow weathered pediplains as moderate to poor (Fig. 5). Similar observations were made in different sites [9] [10] [12].

Land use/ land cover. The land use/land cover map was prepared from the satellite image. Supervised and unsupervised classification techniques were used in ERDAS imagine 2010 (Fig. 6). The satellite image was visually interpreted for the information of land use activities and land cover by making use of the interpretation keys. According to supervised classification, the watershed was classified in to five major types and accuracy of unsupervised and supervised classifications was found as 84.24% and 87.63% respectively. The study indicated that the supervised classification method was more accurate as the accuracy was higher compared to the unsupervised classification.

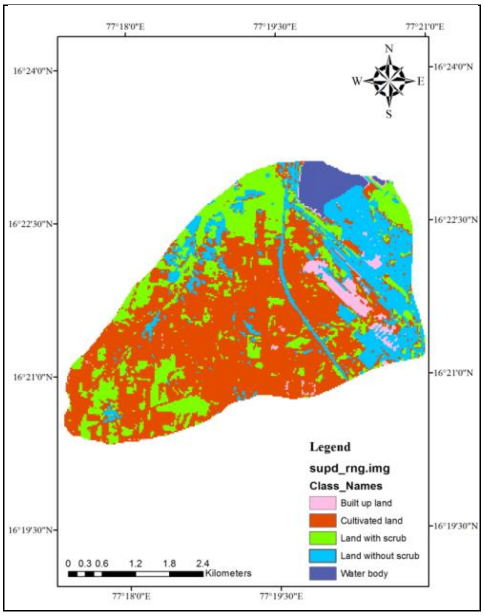

Figure 6. Land use/land cover map of Rangapur watershed

Development of water resources conservation plan based on priority

Watershed prioritization is one of the most important aspects of planning for implementation of its development and management of water resources. The present study demonstrates the usefulness of remote sensing and GIS for prioritization of the Rangapur watershed. The raster thematic maps like drainage, slope, hydro geo-morphology, soil and land use/land cover were considered for the prioritization. In the drainage network, high priority was found to 1st and 2nd order streams because of steeper slopes, the runoff generation will be more and low priority was found to 3rd and 4th order streams because of gentle slope and nearly flat slope. In case of slope of the watershed, high priority was found to 10 to 20%, 20 to 45% and more than 45% slope. Whereas, low priority was considered for the slope range of <1% and 1 to 4%. For hydro geomorphology, low priority was found to valley and high priority was found to shallow weathered pediplain because of poor ground water status. In case of soil, high priority was found to clay soils, in this type of soils runoff expected is more because of low infiltration and low priority was found to sandy clay loam and clay loam because of higher proportion of sand and expected infiltration will be more. Lastly for land use/land cover, high priority was found to cultivated land and land without scrub because of no vegetation and most of the soils are rich in clay content so runoff in these areas are more and low priority was found to water body and land with scrub, it obstruct the runoff water to flow as runoff and make it to infiltrate in to the soil. All these features were calculated in raster calculation and finally water resources conservation map (Fig. 7) was prepared using the criteria given by NRSA under Integrated Mission for Sustainable Development.

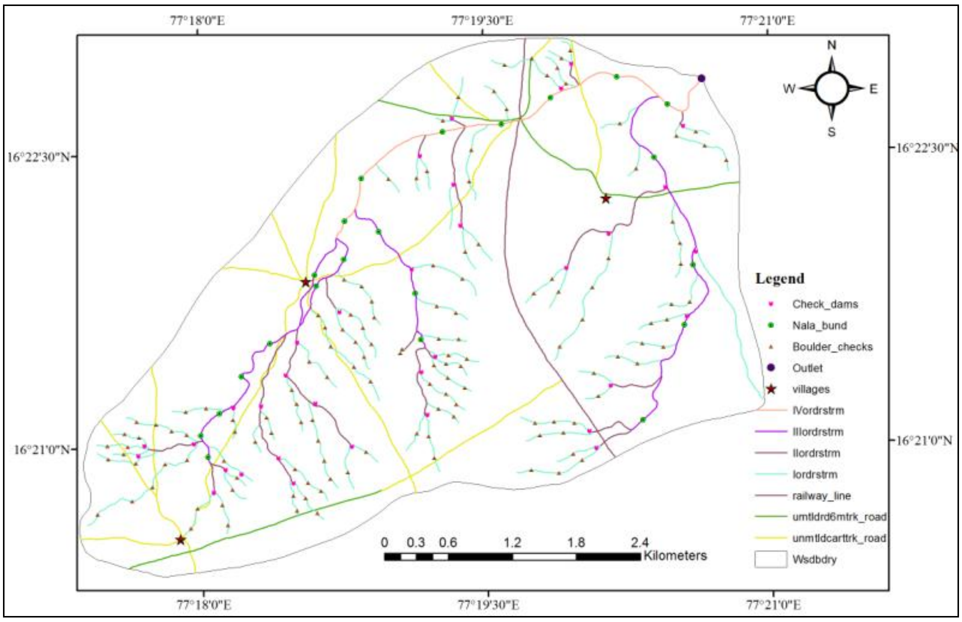

Figure 7. Water resources conservation plan of Rangapur watershed

The water resources conservation plan consists of 34 check dams (up to 3% bed slope where water table fluctuation is high, stream is influent & intermittently effluent, minimum of 25 ha of catchment is desirable, the crest wall of the dam should be strong and well defined), 22 nala bunds (< 3.5% bed slope, recommended up to 4th order and higher streams, deeper nala facilitates more water-spread area, reduce the velocity of flow) and 141 boulder checks (provided at first order streams, areas where boulders and stones are available, the bund is sprinkled with grass seeds, planted with euphorbia, khus, agave, lantana plantings in the fence and non browsable plants are preferred).

CONCLUSION

The study concludes that remote sensing and GIS technologies can be used for scientific planning and management of natural resources. The generation of alternative land use/land cover practices for natural resources management involves careful study of thematic maps both individually and integrated basis as well. Keeping in view the conservation plans are generated on systematic assessment of physical capability, economic viability and technical feasibility. The thematic maps *viz*. drainage, slope, hydro geomorphology, soil and land use/land cover were prepared and integrated to generate location priority raster to locate water conservation structures like 42 check dams, 22 nala bunds and 141 boulder check dams were proposed at high priority location to reduce the velocity of flowing water by obstruction and thereby increase the percolation of water for ground water recharge.

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PLAN KONZERVACIJE VODENIH RESURSA SLIVA RANGAPUR U BASENU SREDNJEG KRISHNA UPOTREBOM DALJINSKE DETEKCIJE I GIS

Mallika Kurdi[1], Banda Maheshwara Babu[1], Gejjala Venkataravanappa Srinivasa Reddy[1], Basavaraj Shivanagouda Polisgowdar[1], Rajesh Neralikere[2]

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Sažetak: Istraživanje je sprovedeno u oblasti sliva Rangapur površine 2079 ha, sušne oblasti u sredini basena Krishna. Predložen je plan prioriteta za održivi razvoj ove oblasti pmoću GIS i daljinske detekcije. The IRS P6 LISS III snimci su korišćeni za pripremu mapa pokrivenosti i namene zemljišta i hidrogeomorfologije. Geološki, veći deo sliva je stenovit. Glavne geomorfne jedinice su mapirane. Arc Hydrology model programa ArcGIS 10 je upotrebljen da se predlože različite structure za konzervaciju zemljišne vlage i skupljanje vode. Iz ispitivanih uzoraka predložene su različite lokacije duž tokova. Tako je preporučeno da je sakupljanje vode posebno važno za povećanje punjenja podzemnih izvora vode, uz obezbeđenje dopunskog navodnjavanja.

Ključne reči*: Check dam, Nala bund, Boulder checks, hidro geomorfologija, pokrivenost, sliv, daljinska detekcija, GIS, skupljanje vode, punjenje podzemnih izvora*

Prijavljen: *Submitted*:	02.03.2015.
Ispravljen: *Revised*:	30.07.2015.
Prihvaćen: *Accepted*:	02.10.2015.

Univerzitet u Beogradu Poljoprivredni fakultet Institut za poljoprivrednu tehniku	University of Belgrade Faculty of Agriculture Institute of Agricultural Engineering
Naučni časopis ***POLJOPRIVREDNA TEHNIKA***	Scientific Journal ***AGRICULTURAL ENGINEERING***
Godina XL Broj 4, 2015. Strane: 9 - 18	Year XL No. 4, 2015. pp: 9 - 18

UDK: 635.1:631

Originalni naučni rad
Original scientific paper

INFORMATIONAL AND CONCEPTUAL DESIGN OF A PEANUT TRACTOR DRIVEN HARVESTER FOR MEXICAN AGRICULTURE

Jaime Cuauhtemoc Negrete*

Antonio Narro Agrarian Autonomous University, México

Abstract: In Mexico, the peanut crop production has declined due to low productivity and profitability of the crop. Since 1983 when the record was 170.433 ton production was obtained with a yield of 2,04 t·ha^{-1}. Since today is production is 94.848,58 tons, with a yield of 1,77 t·ha^{-1}. The country has a shortage of about 100.000 tons per year to meet domestic demand, so you can identify regions with greatest potential to find business opportunities and leverage the domestic market demand. To increase crop productivity peanut is due to promote mechanical harvesting in Mexico, producers require machines with easy and economical operation that can harvest under a wide range of conditions. No mechanical systems or machines are designed in the country to harvest peanuts so there are restrictions on the adoption of imported peanut combine models: a. - high initial cost of acquisition b. - differences with local farming systems c. - difficulty of proper maintenance and spare parts.

For the foregoing reasons this work aims to contribute to the informational and conceptual design of a peanuts harvester for medium size farmers in Mexico.

***Key words**:* agricultural mechanization, harvester combine design, Mexico, peanuts, tractor driven combine

INTRODUCTION

In Mexico the peanut crop production has declined due to low productivity and profitability of the crop. Since 1983 when the record was 170.433 ton production was obtained with a yield of 2,04 t·ha^{-1}. Since today, production is 94.848,58 t·ha^{-1}, with a yield of 1,77 t·ha^{-1} [21].

To reap the producers in San Luis Potosi tear kills manually and reach harvest between 1.3 t·ha^{-1}. Under rained conditions this practice is the most expensive so using a thresher would lower production costs and be more profitable crop, since this production

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costs 4.965 Mexican pesos would be obtained without machinery increased to 7.860 Mexican pesos [5].

The peanut acreage decreased by high production costs 11.000 to 14.000 Mexican pesos and low productivity 1.5 t·ha^{-1}. The domestic market is not supplied by domestic production. No assessment of varieties demanded by the market for the snack industry and oils demonstrating the technological components; use of new varieties, organic fertilizers and mechanization peanut crop. Seeder, combine, shelling machine and toaster needed to increase production cutting times, increasing the increments been desired by machinery, improving production systems at low cost and profitability. Having unwillingness to technological change, high attachment to traditional methods, low availability to innovation, few lines of research, lack of support for the development of new research, lack of adaptation of existing technologies [13].

In Puebla peanut harvest has reduced its costs by up to 32% production costs range from 11 to 15.000 Mexican pesos and selling kg for 6-7 Mexican pesos, with a yield of 1 to 1.5 t·ha^{-1}. Producers have an average of 3 hectares, and 20 hectares in Chihuahua. 20 average wages in a week is required only for manual starting in one ha. Another 20 for threshing. Combine with rises in two-hour ha. In 5.700 Mexican pesos manual harvesting is spent, and mechanized costs 3.100 to 2.400 Mexican pesos [10]. Mechanized harvesting process is necessary in order to hand over to pick the length of time of operations, reduce the number of employees, increase productivity and reduce costs by up to several times [33].

The analysis of the situation of the park peanut harvester Mexico is not possible because the country lacks the culture of having a census and an organization that is dedicated to information of agricultural machinery of any kind (tractors, combines, implements etc.) [20]. So questions about the park peanut harvester and strippers as they are; it is efficient, modern, replenishment of this, the ratio strippers for harvesters stay in the air until action was taken. A peanut harvesting system depends on physiological, social, economic and technological factors. No mechanical systems or machines are designed in the country to harvest peanuts so there are restrictions for adopting imported peanut combine models: a. high initial cost of acquisition, b. differences with local farming systems, c. difficulty of proper maintenance and spare parts.

To increase the productivity of peanut crop should promote mechanical harvest in México, farmers require machines with easy and economical operation under a wide range of conditions and design a harvester suitable for medium sized properties [21] [22]. For the foregoing reasons this work aims to contribute to informational and conceptual design of a peanuts harvester suitable conditions for medium size farmers in Mexico. The time spent on manual harvesting and threshing between 300 and 400 hours·ha^{-1} [15]. In China the peanut harvest is low efficiency and higher labor intensity, with a high cost of production [11]. In Taiwan an average of 1128 labors hours per ha was needed to produce peanuts, one fifth of which was for harvesting usually done by hand [35] in India Present practice of hand harvesting and threshing groundnut consumes huge amount of labor to the magnitude of 84 man-h·ha^{-1} [24].

Several authors related the operation of peanut harvester machines; peanut pickers – threshers [15], [14], [25], Peanut Combines [23], green peanut Combines [31].

Factors influencing the selection, performance and design of peanut harvester:

The Machine. 1. center of gravity, 2. capacity, 3. working speed, 4. characteristics of lifting mechanisms, 5. threshing and cleaning assets and internal organs cut driving, 6. wheeled power source. *The Field.* 1. variety, 2. crop status, 3. crop plantation system and row spacing of plants, 4. along the furrows and access status, 5. property size, 6. terrain declivity.

Basic function peanuts combines include, [8] and [7]: 1. lift the vines into combine, 2. thresh the pods from the vines, 3. separate pods and vines, 4. remove the stems from the pods, 5. deliver clean, undamaged pods into the hopper.

Various attempts to design a economic peanut harvester are carried out, which are related below.

A small self-propelled one way operation groundnut combine harvester was developed in the National Chung Hsing University. The criteria of the design were that the groundnut vines with the pods could be pulled up from the ground and put in rows. Fields loss during mechanical operation could be low due to high moisture content of stumps. The combine was small in size and driven a 15 HP diesel engine. In this machine an automatic hydraulic height control to maintain the stems at pickup high. When working on an uneven ground, a stem combine device and a string type pod ripper controlled the height [35].

A peanut harvesting equipment suitable for operation by a 35 Hp tractor was designed, developed and tested at the department of biological and agricultural engineering UPM, Malaysia. The equipment consists of adjustable V-shaped digging blade where the angle of penetration can be easily adjusted with the help of bolts and nuts. Double discs lifter for gripping the loosened plant above the soil surface follows the digging blade. The loosened plant enters into a threshing mechanism, which consists of two cylinders with different numbers of fingers to achieve the stripping operation without dragging and clogging the pods then transfers them to the tank at the end of the equipment via conveyor. The weight is the 315 kg and the cost US$ 1.455. Hence the new peanut harvesting equipment was designed to provide proper and efficient digging blade (V-shaped), with the following features: suitable clearance between cylinders and their concave (35 mm), suitable spacing between concave bars (25 mm) and conveyor wire mesh (20 mm). The total power of single row equipment was about 15kW (20 HP) [1]

Design, develop and evaluated a tractor operated groundnut combine harvester in a department of agricultural machinery department of the Tamin Nadu Agricultural University. As the combine harvester has to perform the dual operations viz., harvesting and threshing, the groundnut harvesting mechanism, conveyor and threshing mechanism have to be mounted integrally to carry out harvesting and threshing simultaneously. The groundnut combine with the following components should perform the desired functions. The harvester for penetrating into the soil to the required depth and digging out the groundnut crop with pods. Pickers conveyor pick up units of sufficient width to allow for picking and conveying the dugout crops with pods from the soil surface. Collection chamber for collecting the crops with pods conveyed by the picker conveyor. Belt conveyor to convey the collected crop from end the harvester to other end. Elevator for elevating and feeding the conveyed crop with pods from the belt conveyor into the feeding chute of threshing unit. Feeding chute to regulate the flow of crops conveyed by the elevator into threshing cylinder. Thresher cylinder for separating the pods from the vines of groundnuts crops. Blower for blowing out the chaff and dust particles after the threshing operation. Sieve for separation of foreign particles, vines, etc. from the pods. The operation groundnut combine harvester resulted in 39% and 96% saving in cost and time respectively, when compared to conventional method of manual digging and stripping [24]

Designed and developed a functional model in Romania of a machine that achieves direct harvesting of peanuts by: dislocation of the plants, pulling of the plants from the soil, detachment of the pods out of plants, separation and impurities [3].

A 4HJL-2 harvester for peanut picking -up and fruit-picking was developed. This machine is mainly composed of a chain nylon elastic tooth pick-up device, transmission device, take off equipment, elevator set fruit device parts, such as using knapsack structure design, supporting power for Yangzhou 30 tractor, unit speed 52 $m \cdot min^{-1}$, collecting 57 $m \cdot min^{-1}$. Conveying speed conveyer 23 grads inclination. It can finished once peanut collecting, transportation, picking fruit, such a cleaning, set fruit, reduced human use. Field experiments show that the machine work performance is good, the collection rate 99.1 % the los rate was 3.2 %; productivity was 886 $kg \cdot h^{-1}$ [11]

At present only the peanut harvester 4HLB2 which co-developed in China by Qingdao Agricultural University, Qingdao Technological University, Harbin Institute of Technology and the Qingdao Hongsheng Auto Fittings Co. Ltd. company [6]. Currently has economic impact and technically as it is marketed worldwide, demonstrating that when the state promotes cooperation between academic institutions and companies for agricultural mechanization.

[31] Defined the functional analysis of agricultural machines, this has several components that work together as a system, and may be divided into two sub systems ;process system or support systems. The process system are those components of the machine that actually perform the functions that the machine is designed to perform and may be divided in three types; reversible, non-reversible and non-directional. The support system are the parts that support or aid the process system in performing their function and may be categorized as framing, power or control system. [27] Suggest the usage of the technique of the function structure for starting the development of agricultural machinery concepts.

To design in modern agricultural machinery was already systematized methods to improve and reduce time, money and effort, [17], [27], [34], [2].

[17] indicates actions to be executed for machine design ;lifting the physical characteristics of operation, perform the theoretical study of operation, and the sequence of events, the study of existing mechanisms and their associations, technical feasibility select systems and economic, to define the concept of machine design and build experimental prototype.

For the process of development of agricultural machinery are; design planning, informational design, conceptual design, preliminary design, detailed design, preparation for production, launch and validation, [27]. Informational design consisting of the detailed analysis of the design problem, looking for all the information necessary for full understanding of this design. The result obtained at the end of this phase, are the design specifications, which are a list of objectives that the product to be designed to meet, [26] from there are defined functions and required product properties and possible restrictions [26]. Conceptual design is defined as the stage looking to understand how the selection of product design based on your specifications resulting from informational project is determined.

MATERIAL AND METHODS

For informational design the information was compiled from databases websites of domestic and foreign government agencies, patents, academic papers, journals, conferences, manufacturers, importers and distributors, scientific journals, professional thesis, newspaper articles, books, etc.

For conceptual design was followed in this project the morphological matrix methodology described by [2] and [34]. According [2] when a project is initiated and developed, it is split into a sequence of events, in a chronological order to form a model each of these events can be divided into phases. Morphological matrix method is defined as the division of the problem in two or more dimensions, based on the required functions of the system to be designed, then the maximum number of alternatives to accomplish each of the functions are listed, which are organized in a matrix in which the various combinations can be analyzed [2].

To calculate the track width was used the equation given by [19]:

$$B = m \cdot (n + 1) - 2 \cdot C_{ext} - b \tag{1}$$

where:

B [mm] - track width,
m [mm] - row spacing,
n [-] - number of row under the tractor,
C_{ext} [mm] - area outside the plant protection,
b [mm] - width of the tire.

RESULTS AND DISCUSSION

[16] relates that the varieties grown in Mexico are regionalized, for example, varieties erect growth habit Virginia type of large seeds are the most commonly grown in Guerrero and Morelos. The creeping growth habit and Spanish Runner type of small seeds are grown in Morelos and Puebla. The creeping Virginia type varieties of large seeds that require more labor to harvest handling and cultured in minimum area and southern Morelos, finally the fastigata subspecies creeping growth habit type Valencia having 3 smaller seeds per fruit and purple cuticle backyard grown in Puebla. In the table 1 show area, production and yield, distance between rows and between plants in states with more production in Mexico.

Table 1. Area, production and yield, distance between rows and between plants in states with more production in Mexico according to several sources

State	*Surface sown [ha]*	*Production [t]*	*Yield [t·ha^{-1}]*	*Distance between rows*		*Distance between plants [cm]*	
				Creeping varieties [cm]	*Erect varieties [cm]*		
Sinaloa	*16.430,10*	*25.395,80*	*1,56*		*75*	*9 seeds·m^{-1}*	*[4]*
Morelos	*941,30*	*1.719,16*	*1,83*	*Short-guide 50 Long-guide 90*	*75*	*40*	*[9]*
Guerrero	*2.434,60*	*3.151,54*	*1,58*		*48-60*	*25-40*	*[16]*
S. Luis Potosi	*3.436,00*	*3.875,50*	*1,13*		*90*	*25*	*[5]*
Veracruz	*583,5*	*662,23*	*1,16*	*75-80*	*60*	*20-30*	*[12]*
Puebla	*6.317,90*	*6.980,70*	*1,10*	*75*		*40*	*[16]*

Informational design about peanut cultivation in Mexico. [28] Found in study of the varieties grown in Mexico the length of pods are between 2,95 and 5,17 and a average of 3,57 cm. In the Tab. 1 show area, production and yield, distance between rows and between plants in states with more production in Mexico according to several sources, and in the Tab. 2 show main characteristics of some varieties grown in Mexico and in Fig. 1 the peanut harvester design requirements. The design parameters of any root or tuber crop harvester effects the performance of the machine [30]. In the Tab. 3 is shown the peanut harvester design requirements.

Table 2. Main characteristics of some varieties grown in Mexico [16]

Variety	Habit growth	Height plant [cm]	Days flowering	Yield straw [$t{\cdot}ha^{-1}$]	Fruit yield [$t{\cdot}ha^{-1}$]
RF-214	creeping	35	35	4.3	1.8
Huitzuco93	creeping	65	33	5.8	1.6
A-18	erect	54	33	4.0	1.7
Ranferi Diaz	erect	57	35	4.0	1.7
Rio balsas	erect	58	33	5.5	1.7

Table 3. The peanut harvester design requirements

Require-ments	Plants pick-up width	Area proposed	Appropriate travel speed	Good stability	Low cost	Low weight	Ease of transit	Low power	Maintenance interval	Width track
Quantify	1 m	20 ha or more	Max 40 $km{\cdot}h^{-1}$	Lower gravity center	10.000 -14.000 $ US	Less 3.500 kg	Multiple of 75 cm	45 HP	More 300 hours	2800 mm

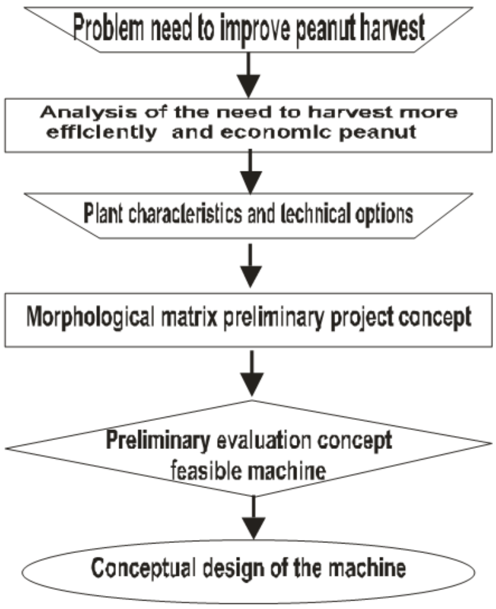

Figure 1. The peanut harvester flowchart of the project phases

A.-To provide Traction and power	A1.-Animal drawn	A2.-Two wheels tractor	A3.-Pull type Harvester	A4.-Traction Driven	A5.-Self-propelled
B.-To provide picking	B1.-Pick up header with rigid fingers	B2.- Pick up header with Iron type spring	B3.- Pick up header with Leaf spring fingers	B4.- Pick up header with flexible fingers with	B5.- Collecting chamber
C.-To Provide threshing	C1.-five cylinders	C2.-four cylinders	C3.-One rotor Axial threshing	C4.-Two rotors Axial threshing	C5.-Spiral arc panel threshing
D.-To provide cleaning	D1.-Radial flow	D2.-Cross flow fan	D3.-axial flow blower cross axial position	D4.-axial flow blower longitudinal axial	
E.-To provide conveying	E1.-Screw conveyor	E2.-Pneumatic conveyor	E3.-Bucket conveyor	E4.-Belt conveyor	
F.-To provide storage	F1.-Hooper In the combine	F2.-Hooper Trailer	F3.-Bagging System		

Figure 2. Matrix peanut functions and alternatives for peanut tractor driven harvester conception

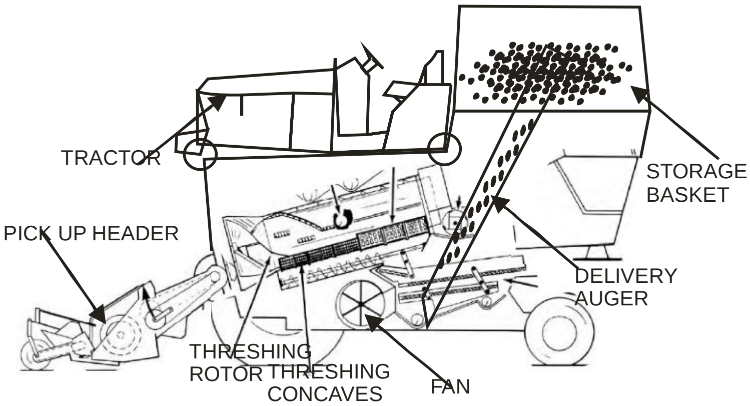

Figure 3. Tractor driven peanut combine QKX13

Conceptual design. The conceptual design phase of a harvesting equipment involves abstracting to find the essential problems of mechanization, establishing function structures for machine, searching for solution principles, combining solution principles into conception and selecting a suitable conception [34].

In the Fig. 2 show he peanut harvester flowchart of the project phases.

For the matrix in Fig. 2 can specify the desired machine concept; (A4-B1-C4-D1-E1-F1), the combine will be driven by the tractor has a pick up head, axial two rotors threshing system, radial flow fan cleaning system, convey system by screw, and storage of the product harvested by hopper installed in the combine and will have a track width of 2.80 m calculated according to equation (1) [32] the harvester with a threshing axial system are better able to harvest and reduce mechanical damage, compared to the harvester with threshing radial system.

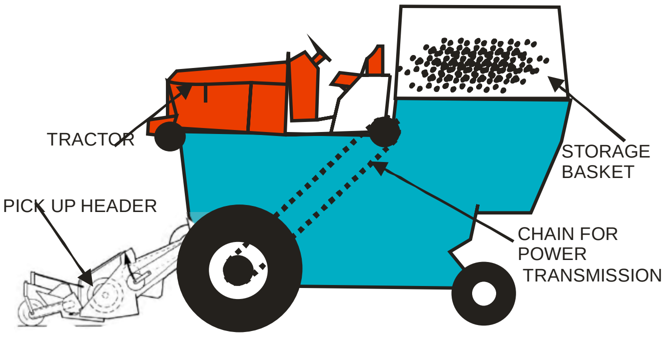

Figure 4. Tractor driven peanut combine QKX13 power transmission system schematic

According [18] the pull type combine for use the engine and the tractor traction to move and drive mechanisms have lower cost to self-propelled combines, but has low operational performance, difficulty maneuvering and problems with the coupling system, by the other hand, the self-propelled combine presents minimal problems maneuver, the direction easily control, and high initial cost of acquisition and maintenance. So the peanut tractor driven harvester has the advantages of the pull type and self propelled combines without the disadvantages of both.

CONCLUSIONS

The morphological matrix method proved be effective for the conceptual design of a peanut harvester for medium sized properties in Mexico. It should continue with the next phases of design (preliminary design, detail design, prototype construction, test and evaluation and final documentation of complete machine). So you can test the ability of this machine in the production of peanut efficiently and economically.

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INFORMACIONA I KONCEPTUALNA KONSTRUKCIJA TRAKTORSKOG KOMBAJNA ZA KIKIRIKI ZA MEKSIČKU POLJOPRIVREDU

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Sažetak: Proizvodnja kikirikija u Meksiku je opala zbog male produktivnosti i profitabilnosti useva. Od 1983, kada je proizvedeno 170.433 tona, sa prinosom od 2.04 $t \cdot ha^{-1}$, danas se proizvodi 94.848,58 tona sa prinosom od 1.77 $t \cdot ha^{-1}$. Zemlji nedostaje oko 100.000 tona godišnje za domaće potrebe, pa treba identifikovate regione sa najvećim potencijalom za zadovoljenje potreba domaćeg tržišta. Za povećanje produktivnosti predstavljena je mašinska žetva kikirikija u Meksiku, pa proizvođači traže mašine za jednostavnu i ekonomičnu upotrebu u različitim uslovima žetve. Domaće mašine nisu konstruisane pa postoje ograničenja u prilagođavanju uvoznih kombajna: a. visoki početni troškovi, b. neusklađenost sa lokalnim uzgojnim sistemima, c. teškoće sa pravilnim održavanjem i rezervnim delovima.

Iz navedenih razloga, cilj ovog rada je da doprinese informacionoj i konceptualnoj konstrukciji kombajna za kikiriki za srednje farme u Meksiku.

Ključne reči: poljoprivredna mehanizacija, konstrukcija kombajna, Meksiko, kikiriki, kombajn sa traktorskim pogonom

Prijavljen: *Submitted*:	14.03.2015.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	12.09.2015.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XL
Broj 4, 2015.
Strane: 19 - 26

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 19 - 26

UDK: 665.3:577

Originalni naučni rad
Original scientific paper

STORAGE STABILITY STUDIES ON VITAMIN A FORTIFIED SUNFLOWER (*Helianthus annuus*) OIL

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Abstract: Fortification of foods is a well sighted path for solving nutritional problems in developing society. Common vegetable oil such as sunflower oil was utilized for fortification with Vitamin A. The objective of this study was to fortify the sunflower oil with vitamin A as per World Food Program (2011) guideline and to test the stability of vitamin A during different storage, packaging and deep fat frying conditions. The fortified oil was analyzed for a period of 5 months for its physic-chemical properties under various study conditions. The result of this study showed that vitamin A added to oil stored at room temperature under dark condition was stable for the entire study period. The retention of vitamin A in deep fat fried sunflower oil was found to be 85%, 68%, 49%, 38%, 19% and 7% for first, second, third, fourth, fifth and sixth frying, respectively. Further from the study was understood that there was no significant difference in the physic-chemical properties of the fortified oil during the study period. As a whole, the results of this study clearly revealed that Vitamin A added to refined oil remains stable during commonly adopted storage conditions while there is a significant reduction in vitamin A content during frying cycle.

Key words*: fortification, physic-chemical properties sunflower oil, storage, vit. A*

INTRODUCTION

Deficiency of vitamin A is a common health complication in many parts of the world [1]. Vitamin A insufficiency continues to be a major public health nutritional dispute in India. The prevalence of Bitot's spot, the objective sign of clinical vitamin A deficiency (0.8%) was higher than the figures endorsed by the WHO (0.5%), indicating the public health implication in rural pre-school children of India [2]. Analysis of blood samples revealed that the overall median vitamin A level was16.8 mg/dL, and ranged

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from a low 9 mg·dl^{-1} in Madhya Pradesh to a high 20.1 mg·dl^{-1} in Tamil Nadu. About 62% of children in general, had vitamin A levels of <20 mg·dl^{-1}, indicating sub-clinical vitamin A deficiency (*VAD*). The proportion of children with sub-clinical *VAD* was significantly higher among 3-5 year children (63.1%) compared to 1-3 years (59.6%) [3]. The median intake of vitamin A (124 μg·CU^{-1}·day^{-1}) was grossly deficient as compared to *RDA* 600 μg·CU^{-1}·day^{-1} in all the States [4]. A consequence of severe vitamin A deficiency, especially in children, is ocular lesions leading to xerophthalmia and blindness (*WHO*, 1982). Acute and subclinical deficiency of vitamin A is also known to increase the risk of respiratory infections and diarrhea [5] and thereby influence morbidity and mortality rate in infants [6]. The considerable cause of vitamin A deficiency are incompetent dietary intake of the preformed retinol or precursors of vitamin A, increased vitamin A requirement in certain physiological or pathological conditions, inadequate absorption, or loss of intestinal contents in diarrhea [7]. The three main mediation approaches across micronutrient malnutrition are: direct supplementation of micronutrients, dietary improvements and micronutrient fortification of common foods [7]. Fortification with vitamin A sounds to be most adequate approach for the prevention and control of vitamin A deficiency in various parts of the world [8]. It becomes very significant to select an appropriate carriage which is most suitable for fortification with vitamin A. The use of vegetable oils is increasing very rapidly in all regions of India. Oil is the most suitable vehicle for vitamin A fortification and efforts to fortify vegetable oil with retinyl palmitate have been well-established at a low cost. The oil matrix protects against the oxidation of vitamin A during storage, improves stability of the retinol, and facilitates the vitamin's absorption by the body [9]. Sunflower oil provides significant health benefits and supplies more vitamin E than any other vegetable oil. Since sunflower oil has less saturated fat it lowers cholesterol more significantly which reduces the risk of many heart problems [10]. Sunflower oil contains the highest percentage of poly unsaturated fatty acid (71%) with the predominant presence of linolenic acid which makes this oil suitable for use as a salad oil [11]. The objective of this study was to evaluate the stability of vitamin A fortified in sunflower oil during various conditions of storage, packaging material and during deep fat frying of food.

MATERIAL AND METHODS

Particular brand of refined sunflower oil manufactured in specific date was purchased from local market and used throughout the study. Pure retinyl palmitate was purchased from Nicholas Piramal India limited, Thane and used for the fortification. All chemicals used for analysis were of analytical grade and purchased from *SGS* private limited, Chennai.

Vitamin A fortification. A large batch of vitamin A fortified sunflower oil was prepared by heating the commercial oil to 45-50°C [12]. The recommended dosage [13] of retinyl palmitate at the rate of 30 IU·g^{-1} of sunflower oil was added by constant stirring to ensure complete mixing of vitamin A with the sunflower oil.

Storage study analysis. One liter fortified oil was packed in two different packaging materials viz, *PET* bottle and nylon pouch (commercially accepted) and stored at room temperature under normal light and dark Conditions. Required quantity of control and fortified oil was drawn from each packaging material analyzed for its various physico-chemical properties viz, moisture content, refractive index, color, saponification value, acid value, free fatty acid value, iodine value, and peroxide value as per the methods described by *FSSAI* (2012) [14].

Deep fat frying and vitamin A retention. Deep frying of papadum was performed using fortified sunflower oil to check the Vitamin A retention after frying. Totally six frying were carried out in two cycles. First cycle was performed with a representative portion of Vitamin A-fortified sunflower oil heated in a stainless steel frying pan and three portions of papadum (15g) were fried. The left out oil was stored for three days and second cycle was repeated in the same manner. After each frying, an aliquot of frying oil (approximately 100 ml) was drawn for the analysis of Vitamin A and other physico-chemical properties. The practical significance of this trial was to determine the retention of Vitamin A during repeated use of the same oil for frying foods during common household practice and during extreme situations.

Quantification of vitamin A. The analysis of vitamin A in oil and in food samples was carried out according to the method of *HPLC* or high pressure liquid chromatography [15]. The method consisted of weighing aliquots of oil, carrying out saponification and extraction of the lipid fraction, evaporating ether extract, and dissolving the residue in n-hexane, and injecting the final extract in the chromatograph. The conditions used for *HPLC* analysis were as follows: (a) stationary phase: Lichrosorb Si 60.5 m, length 12.5 cm and internal diameter 4 mm; (b) moving phase: n-hexane containing 2% of isopropanol (isocratic); (c) flow rate: 1 ml·min^{-1}; (d) injection volume: 10-50 ~1; (e) pressure: about 40 bar; (f) detection: by fluorescence (excitation: 325 nm and emission: 480 nm). The amount of vitamin A in samples was calculated by measuring the area under the peak of the sample and comparing it with the area under the peak of the known standard of vitamin A, which was made by saponification of pure all-trans-retinyl acetate in cotton seed oil (*USP* capsule), and used for external calibration.

Statistical analysis. Data collected during the study period was statistically analyzed using *SPSS* 20.0 for windows. The mean, standard deviation, coefficient of variation in percent (*CV* %) and the test of significance were performed.

RESULTS AND DISCUSSION

Stability of Vitamin A in fortified sunflower oil during storage. Fortified sunflower oil sealed in nylon pouch and stored under normal light and dark condition, retained 97 and 100% vitamin A respectively for a period of 5 months. On the other hand fortified sunflower oil packed in *PET* bottles retained 98.2 and 100% vitamin A respectively, for the same condition. Several studies were reported on fortification of Vitamin A in different food products also confirms the study results [16] [17]. The stability of vitamin A in different vegetable oils was studied and found that stability of vitamin A decreases on exposure to light. The content of added vitamin A to the soybean oil which was protected against light was unaltered up to six months. The outcome of the quality assessment of the fortified sunflower oil during storage in the different packaging material and storage conditions are given in Tabs 1, 2, 3, 4.

The fortified oil stored in nylon pouch under light condition has peroxide value between 0.63 to 6.43 meq·kg^{-1}, IV was 130-133.86, free fatty acid value was between 0.03-0.10%, acid value was between 0.050-0.085 mgKOH·g^{-1} and saponification value was between 190-194 mgKOH·g^{-1} and for the oil which was stored under dark condition has peroxide value between 0.63-4.02 meq·kg^{-1}, IV was 130-133.16, free fatty acid value was between 0.03-0.08% acid value was between 0.050-0.07 mgKOH·g^{-1} and saponification value was between 190-193.61 mg KOH/g. The fortified oil stored in *PET* bottle under light condition has peroxide value between 0.63 to 3.24 meq·kg^{-1}, IV was 130-133.62, free fatty acid value was between 0.03-0.10%, acid value was between 0.050-0.072 mgKOH·g^{-1} and saponification value was between 190-192.71 mgKOH·g^{-1} and for the oil which was stored under dark condition has peroxide value between 0.63-2.87 meq·kg^{-1}, IV was 130-132.69, free fatty acid value was between 0.03- 0.08%, acid value was between 0.050-0.060 mg KOH·g^{-1} and saponification value was between 190-191.84 mg KOH·g^{-1}.

Table 1. Storage stability studies of sunflower oil (pouch light)

No	Period of storage	Color	Moisture content (%)	Rf	AV (mgKOH·g^{-1})	FFA (%)	PV (mEq·kg^{-1})	SV (mgKOH·g^{-1})	IV	Vit. A (%)
1	Before fortification	7	0.03	1.466	0.05	0.03	0.63	190.00	130.00	Nil
2	After fortification	7	0.03	1.466	0.05	0.03	0.65	190.32	131.37	100
3	First month	7	0.03	1.466	0.052	0.05	0.74	191.24	132.92	100
4	Second month	7	0.03	1.466	0.055	0.07	1.67	192.42	133.86	100
5	Third month	7	0.03	1.468	0.061	0.08	3.67	193.62	134.12	99
6	Fourth month	7	0.03	1.468	0.07	0.08	5.04	193.96	134.34	98
7	Fifth month	7	0.03	1.468	0.085	0.10	6.43	194.00	134.39	97
8	Mean	7	0.03	1.467	0.054	0.06	1.205	191.83	133.86	100
9	Standard deviation	0	0.00	0.00099	0.012	0.025	2.2567	1.59	1.54	1.22
10	CV (%)	0	0.00	13.21	21.23	11.24	78.36	21.32	12.58	18.9

FFA- Free Aftty Acid, R_f- Refractive Index, AV- Acid Value, PV- Peroxide Value, SV- Saponification Value, IV- Iodine Value

Table 2. Storage Stability studies of sunflower oil (pouch dark)

No	Period of storage	Color	Moisture content (%)	Rf	AV (mgKOH·g^{-1})	FFA (%)	PV (mEq·kg^{-1})	SV (mgKOH·g^{-1})	IV	Vit. A (%)
1	Before fortification	7	0.03	1.466	0.05	0.03	0.63	190.00	130.00	Nil
2	After fortification	7	0.03	1.466	0.05	0.03	0.65	190.32	131.37	100
3	First month	7	0.03	1.466	0.051	0.05	0.94	191.12	132.36	100
4	Second month	7	0.03	1.466	0.053	0.05	1.92	191.96	132.96	100
5	Third month	7	0.03	1.468	0.059	0.05	2.84	193.26	133.07	100
6	Fourth month	7	0.03	1.468	0.063	0.07	3.59	193.54	133.16	100
7	Fifth month	7	0.03	1.468	0.07	0.07	4.02	193.61	133.16	100
8	Mean	7	0.03	1.467	0.052	0.05	1.43	191.54	132.66	100
9	Standard deviation	0	0.00	0.00099	0.0073	0.0163	1.3346	1.42971	1.05534	0
10	CV (%)	0	0.00	7.38	12.22	28.33	59.35	16.52	19.36	0

The FFA, AV, IV, SV and PV got increased for all the samples including control. All the physic-chemical values of fortified oil were within the limits prescribed by World Food Program guidelines for the entire study period. The reason for this increase in all these parameters may be due to the absorption of moisture from the atmosphere, oxidation reaction, heat and light [18]. The free fatty acid values obtained during the entire period of storage was below the maximum value of 0.15% as recommended by World Food Program (2011) [13]. The IV is an index of instauration which gives the molecular weight of their fatty acid composition. The highest level of PV was found in the sample stored in pouch under normal light condition. However, the values obtained were within the acceptable limit of 10 meq·kg^{-1} [18]. The low PV indicated that the oil had lower susceptibility to oxidative rancidity and is suitable to be stored for some more time without any appreciable deterioration. Other parameters like SV, moisture content, refractive index were also within the limits of 188-194 mgKOH·g^{-1} oil, 0.2%, 1.461-1.468 respectively [13]. Subjective examination of the stored oil sample indicated no alteration in the organoleptic properties such as taste, smell, and color of fortified oil.

Table 3. Storage stability studies of sunflower oil (pet light)

No	Period of storage	Color	Moisture content (%)	Rf	AV (mgKOH·g^{-1})	FFA (%)	PV (mEq·kg^{-1})	SV (mgKOH·g^{-1})	IV	Vit. A (%)
1	Before fortification	7	0.03	1.466	0.05	0.03	0.63	190	130	Nil
2	After fortification	7	0.03	1.466	0.05	0.03	0.65	190.32	131.37	100
3	First month	7	0.03	1.466	0.053	0.04	0.68	190.78	132.94	100
4	Second month	7	0.03	1.466	0.055	0.05	0.88	191.54	133.01	100
5	Third month	7	0.03	1.467	0.06	0.07	1.72	192.58	133.49	99
6	Fourth month	7	0.03	1.467	0.068	0.07	2.12	192.63	133.54	98
7	Fifth month	7	0.03	1.467	0.072	0.08	3.24	192.71	133.62	97
8	Mean	7	0.03	1.467	0.054	0.05	0.78	191.16	132.975	100
9	Standard deviation	0	0.00	0.00053	0.008	0.0206	0.949	1.08071	1.21780	1.215
10	CV (%)	0	0.00	7.83	15.84	27.23	83.34	12.52	23.58	18.92

Table 4. Storage stability studies of Sunflower Oil (pet dark)

No	Period of storage	Color	Moisture content (%)	Rf	AV (mgKOH·g^{-1})	FFA (%)	PV (mEq·kg^{-1})	SV (mgKOH·g^{-1})	IV	Vit. A (%)
1	Before fortification	7	0.03	1.466	0.05	0.03	0.63	190	130	Nil
2	After fortification	7	0.03	1.466	0.05	0.03	0.65	190.32	131.37	100
3	First month	7	0.03	1.466	0.05	0.03	0.65	190.45	131.98	100
4	Second month	7	0.03	1.466	0.051	0.05	0.95	191.08	132.18	100
5	Third month	7	0.03	1.466	0.055	0.06	1.23	191.67	132.43	100
6	Fourth month	7	0.03	1.466	0.06	0.07	2.04	191.75	132.62	100
7	Fifth month	7	0.03	1.466	0.06	0.07	2.87	191.84	132.69	100
8	Mean	7	0.03	1.466	0.0505	0.05	0.8	190.705	132.08	100
9	Standard deviation	0	0.00	0	0.0044	0.0186	0.8958	0.71129	0.85345	0
10	CV (%)	0	0.00	7.83	13.128	25.83	53.27	7.84	35.87	17.89

Statistical result depicts that CV (%) among the parameters with peroxide value being the highest; refractive index value was very least while color and moisture content showed no variation. However there was similarity in the peroxide value in all the containers. There was similarity in CV (%) in parameters such as color, refractive index value, acid value and moisture content. However they were no significant differences in parameters such as free fatty acid, saponification value and iodine value (Tab 5). All these results were compared with triplicates with ±SD values.

Table 5.Chemical properties of oils stored different containers and storage conditions

Parameter	f-value	Test of significance
Color	0.00	s
Moisture content	0.00	s
Refractive index	0.03	s
Acid value	0.07	s
Free Fatty acid	0.15	ns
Peroxide value	0.05	s
Saponification Value	0.173	ns
Iodine Value	1.00	ns
Vitamin A	Not aplicable	Not aplicable

Table 6. Stability studies of sunflower oil during deep fat frying

No	Period of storage	Color	Rf	AV ($mgKOH \cdot g^{-1}$)	FFA (%)	PV ($mEq \cdot kg^{-1}$)	SV ($mgKOH \cdot g^{-1}$)	IV	Vit. A (%)
1	Before frying	7	1.466	0.05	0.05	0.63	190	128.21	100
2	First frying	7	1.467	0.104	0.06	4.34	190.46	129.53	85
3	Second frying	7	1.467	00.13	0.06	5.55	190.82	12.70	68
4	Third frying	7	1.467	0.22	0.06	7.99	191.56	129.70	49
5	Mean	7	1.467	0.117	0.06	4.945	190.64	130.16	68
6	Standard deviation	0	0.0005	0.062	0.0045	2.6445	0.57121	0.73699	14.71
7	CV (%)	0	17.83	12.38	77.84	56.37	57.23	56.38	59.36

Table 7. Stability studies after 3 days storage

No	Period of storage	Color	Rf	AV ($mgKOH \cdot g^{-1}$)	FFA (%)	PV ($mEq \cdot kg^{-1}$)	SV ($mgKOH \cdot g^{-1}$)	IV	Vit. A (%)
1	First frying	7	1.467	0.206	0.07	8.23	191.72	13.22	38
2	Second frying	8	1.467	0.31	0.07	8.56	191.86	13.29	19
3	Third frying	8	1.467	0.35	0.08	9.01	191.97	130.34	7
4	Mean	7	1.467	0.31	0.07	8.56	191.86	130.16	19
5	Standard deviation	0.578	0	0.0616	0.005	0.3203	0.10243	0.07889	12.82
6	CV (%)	57.38	21.82	22.38	25.86	26.68	23.23	38.63	28.39

Stability of vitamin A in oil during Cooking. The *HPLC* results revealed that Vitamin A added to sunflower oil was reduced to less than 50% after 3 repeated frying and that it took about 6 repeated frying to destroy the most of the fortified Vitamin A (Tabs 6 and 7). Previous studies on fortification of vitamin A in vegetable oil reported that the biological value of vitamin A fortified vegetable oil is reduced by about half after frying of foods [16].

CONCLUSIONS

The result of this study clearly indicates that the stability of vitamin A palmitate in vegetable oils is satisfactory during its storage and frying. Fortification of common vegetable oils with vitamin A is therefore feasible. The processing and distribution of vegetable oils is well organized and fortification can easily be implemented and is cost effective. Vegetable oils are well liked and relatively inexpensive sources of fat. Refined oil has no cholesterol and is rich sources of other naturally occurring nutrients such as polyunsaturated fatty acids and vitamin E. The average amount of vegetable oil consumed is about 30 g per person per day [19] which if fortified at the rate of 30 $IU \cdot g^{-1}$ can contribute up to 900 IU of vitamin A per day, respectively.

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STABILNOST VITAMINA A PRI SKLADIŠTENJU I KORIŠĆENJU OBOGAĆENOG SUNCOKRETOVOG ULJA (*Helianthus annuus*)

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Sažetak: Obogaćivanje hrane je dobar način za rešavanje prehrambenih problema u društvima u razvoju. Obična biljna ulja, kao što je suncokretovo, upotrebljena su za obogaćivanje vitaminom A. Cilj ove studije bio je da suncokretovo ulje obogati vitaminom A prema uputstvu Svetskog programa hrane (2011) i da testira stabilnost vitamina A u različitim uslovima skladištenja, pakovanja i prženja. Obogaćeno ulje je analizirano u period od 5 meseci. Rezultati su pokazali da je dodati vitamin A bio stabilan tokom celog perioda skladištenja na sobnoj temperaturi u tamnoj prostoriji. Retencija vitamina A pri prženju u dubokoj masnoći bila je 85%, 68%, 49%, 38%, 19% i 7% od prvog do šestog prženja, redom. Nije bilo značajne razlike u fizičko-hemijskim osobinama obogaćenog ulja. Ukupni rezultati studije su jasno pokazali da vitamin A dodat u rafinisano ulje ostaje stabilan tokom skladištenja u uobičajenim uslovima, dok tokom prženja u dubokoj masnoći dolazi do značajnog smanjenja sadržaja vitamina A.

Ključne reči: *obogaćivanje, fizičko-hemijske osobine suncokretovog ulja, vitamin A*

Prijavljen: *Submitted*: 08.04.2015.
Ispravljen: *Revised*:
Prihvaćen: *Accepted*: 21.09.2015.

Univerzitet u Beogradu
Poljoprivredni fakultet
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Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XL
Broj 4, 2015.
Strane: 27 - 34

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 27 - 34

UDK: 637.52

Originalni naučni rad
Original scientific paper

DEVELOPMENT OF *PLS* MODEL FOR RAPID ESTIMATION OF PROTEIN CONTENT OF RICE USING FOURIER TRANSFORM - NEAR INFRARED SPECTROSCOPY

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Abstract: This study attempted the feasibility to use near infrared spectroscopy as a nondestructive analysis method to qualitative and quantitative assessment of rice quality of Central Warehousing Corporation, India. A *PLS* model were developed using rice standards of different concentrations in the near-infrared region (4.000–12.000 cm^{-1}). The developed models ware authenticated using test validation technique. *FT-NIR* spectroscopy with chemometrics, using the *PLS*–first derivative plus vector normalization method could predict the protein content of stored rice samples accurately up to an correlation coefficient (R^2) and residual predictive deviation (*RPD*) values were 0,98 and 7,21, respectively. The error values such as root mean square error of cross validation (*RMSECV*) and root mean square error of estimation (*RMSEE*) were 0,28 and 0,25, respectively, with 11 factors in the prediction model. The developed model was applied to predict protein content in rice samples within 15 seconds. The developed procedure was further validated by recovery studies by comparing with micro Kjeldahl method of protein determination. These results show that *NIR* spectroscopy could hold up traditional techniques in studying qualitative assessment of rice.

Key words*: NIR spectroscopy, rice, protein, wave number, chemometrics, PLS model*

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INTRODUCTION

Rice (*Oryza sativa*) is one of the most important cereal crops in India. It is staple food in most of the Indian states. Eighty per cent of the rice produced in the country is stored at farm level, Food Corporation of India (*FCI*) and Central Warehousing Corporation (*CWC*). In *CWC* and *FCI* are grade the rice based on quality. During procurement, storage and issue time to assess the quality of rice is difficult task and time consuming process.

Proteins are amino acids. In most cereals, the types and amounts of protein significantly affect the end-use of the grain. Proteins in rice grains influence cooking properties. The structural modifications of protein and starch gels may enhance the hardness of the cooked rice prepared from the aged samples [1]. Types of proteins that accumulate in the grain depend on the genotype of the plant, but high temperatures and different nutritional conditions affect the ability of the grain to express the expected suite of storage proteins [2]. Food scientists are interested in knowing the concentration, molecular structure and functional properties of the proteins in foods. The conventional methods used in order to determine the protein content of rice is Kjeldahl method. However, this method is also tedious, required toxic chemicals, destructive, relatively expensive and time-consuming, as well as it require highly skilled operators.

Near infrared spectroscopy (*NIRS*) technique as an advance technology has come to stay in food and petrochemical industries. The NIR spectrum of an organic material gives a global signature of composition based on the assessment of the organic chemical structures containing O-H, N-H and C-H bonds [3, 4]. This technology coupled with the development of chemometric techniques has become a powerful, fast, reliable and non-destructive analytical tool for the measurement of qualitative and quantitative properties in organic materials [5]. The objective of this study was to investigate the capability of using NIR spectroscopy to estimation of protein content in rice.

MATERIAL AND METHODS

Rice samples obtained from Central warehousing corporation, Trichy, India was sorted manually to remove the foreign and undesirable materials then it was used for this study. The required quantity of sample was withdrawn from refrigerator and equilibrated at room temperature (31±2°C) before conducting different tests [6].

FT-NIR spectra were recorded on multipurpose analyzer (*MPA*) (Bruker Optics, Germany) equipped with a quartz beam splitter and highly sensitive lead sulfide detector (12.000–4.000 cm^{-1}) combined with opus 7.2 software. The spectra were acquired in reflectance mode directly on the rice, over the range 12.000–4.000 cm^{-1} [7]. For each sampling, 10 g of rice was analyzed at room temperature and the average spectra were used for further evaluations.

Spectra recorded samples were manually analyzed for creating calibration library of *FT-NIR* spectroscopy. The protein content present in the sample was estimated following Micro-Kjeldahl method as represented by [8] using a laboratory kjel plus equipment (Pelican equipments, model-*REC 22238-A2*, Chennai).

In order to check the accuracy of newly developed *FT-NIR* method, recovery study was conducted by artificially spiking the rice samples and back estimating its amount through the new method.

The standard values were fed into *NIR* library and remaining samples were validated by using suitable chemometric method. The spectral data were analyzed using *PLS* regression with various preprocessing techniques. The *OPUS* 7.2 software package was used for processing the spectral data and *FT-NIR* models were developed with the full calibration data set. In this study three spectral preprocessing methods were applied comparatively; it includes vector normalization, first derivative and first derivative plus vector normalization. The performance of final *PLS* model was evaluated in terms of root mean square error of cross validation (*RMSECV*), root mean square error of estimation (*RMSEE*), residual predictive deviation (*RPD*) and correlation coefficient of determination (R^2). Ratio of standard deviation to standard error of prediction gives *RPD* value (*SD/SEP*). The accuracy of the calibration models is obtained according to the largest values of R^2 and *RPD* and smallest values obtained for *RMSECV* and *RMSEE* values for cross validation.

$$SSE = \sum [\mathrm{Re}\,sidual]^2 \tag{1}$$

where,
Residual = Experimental value - Predicted value

The coefficient of determination (R^2) gives the proportion of variability of the property that is described by the model (Eq. 2).

$$R^2 = \left(1 - \frac{SSE}{\sum (y_i - y_m)^2}\right) \times 100 \tag{2}$$

where:
y_i - i^{ih} observation of experimental value,
y_m - mean of the reference results for all samples.

$$RMSECV = \sqrt{\frac{\sum_{i=1}^{n} (\bar{y}_i - y_i)^2}{n}} \tag{3}$$

where:
n - number of samples in the validation set,
$\bar{y}_i$ - measured and predicted value of the i^{th} observation in the test set, respectively.

The number of *PLS* factors included in the model is chosen according to the lowest *RMSECV*.

RESULTS AND DISCUSSION

A calibration model was developed using protein content standards of varying concentrations in the near-infrared region (4.000–12.500 cm^{-1}) is shown in Fig 1. From the figure it is seen that almost spectra of all samples are parallel. This means that response of the detector for the sample is linear within the range of study and thus may give better results [9].

Fig 2 shows the preprocessed *FT-NIR* spectra of stored rice which has major peaks at absorbance bands (wave numbers) of 3610.2862, 5145.4293, 5623.7151, 6811.7153, 8316.0013 and 10028.5729 cm^{-1}. The peak and depression in the spectra showed the strong and weak absorbance characteristics of rice within the region of study. These true peaks of spectra were selected after smoothing the spectrum to avoid interference due to noise. The fundamental vibrations in the 4.000-3.500 cm^{-1} region are generally due to O–H, C–H and N–H stretching. The presence of hydrogen bonding is of great importance in a range of molecules [10].

Protein molecule has amine group and carboxyl group; hence, the peak may play an important role in the estimation of protein. From the Fig.2, which is observed that the major peaks at absorbance bands or wave numbers of 5145.4293, 5623.7151 and 6811.7153 cm^{-1} may be due to the C=O stretching, first overtone of –CH and first overtone of NH_2 of protein molecule, respectively. Peaks at 8316.0013 and 10028.5729 cm^{-1} may be due to second overtone of symmetric stretching of carboxyl group (–CH) and second overtone of primary amines ($-NH_2$) group, respectively.

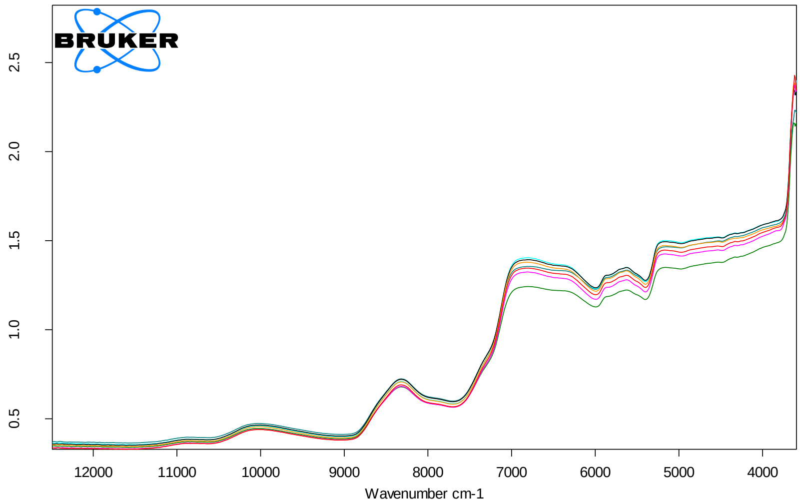

Figure 1. Spectra of rice samples

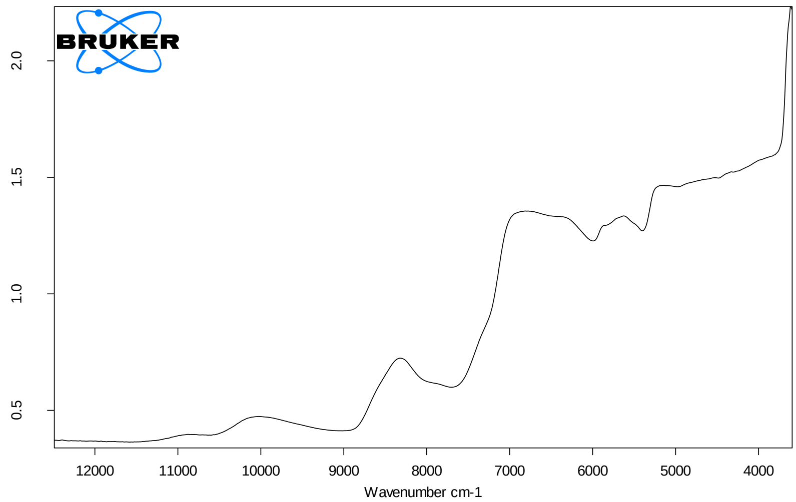

Figure 2. Preprocessed FT- NIR Spectra of rice sample

Protein has a defined amount of energy. When infrared radiation energy is falls on the sample, an energy exchange occurs between the molecules. The most intensive band in the spectrum belong to the vibration and stretching of the carbonyl group (5145.4293 cm^{-1}), followed by the -NH_2 (6811.7153 cm^{-1}), -CH (5623.7151 cm^{-1}) and -CH overtone (8316.0013 cm^{-1}). The vibration of the C=O, -NH_2 and -CH are caused by ingredients such as protein and starch compounds. Some minor peaks observed in the rice spectrum may be due to unknown bond vibrations.

The *NIR* region contains bands that often overlap, making it difficult to extract spectral parameters of the individual bands. Chemometrics have provided a way of overcoming these problems through empirical models that relate the multiple spectral intensities to known analyses in the samples. As the spectra show similar basic *FT-NIR* spectral patterns, mathematical transformations were required to use the *FT-NIR* data for quantitative analysis. Despite the lack of distinct peaks, it has been shown the PLS can extract relevant information for quantitative determinations [11, 12]. PLS algorithm is generally known that the spectral pre-processing methods and the number of *PLS* factors are critical parameters [12].

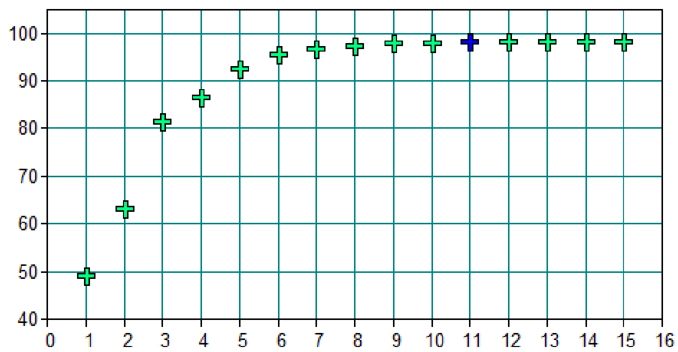

Figure 3. R^2 value as a function of PLS factor

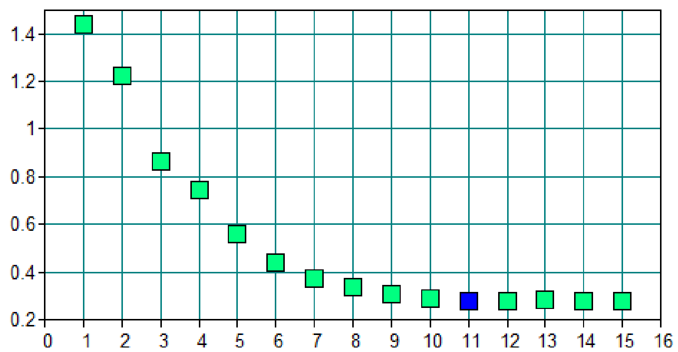

Figure 4. RMSECV as a function of PLS factor

Fig 3, 4 and 5 shows the R^2, *RMSECV* and *RMSEE* values plotted as a function of *PLS* factors for determining protein content with first derivative plus vector normalization method as the pre-processing technique. Seen from figure, *RMSECV* and

RMSEE value decreases sharply with initial factors and maintain the constant value as PLS factor increases from 11 to 15. R^2 value increased up to a *PLS* factor of 11 and maintain the constant value. From the figures, understood that *PLS* factor 11 give satisfactory results for estimation of protein content in rice. From the figures, it is observed that the optimum number of factors is determined by the highest values for R^2 and lowest values of *RMSECV* and *RMSEE*. *PLS* regression method gave R^2, *RMSECV* and *RMSEE* values of 0,98, 0,28 and 0,25, respectively. The results of this study clearly indicated the efficiency of *FT-NIR* for this application.

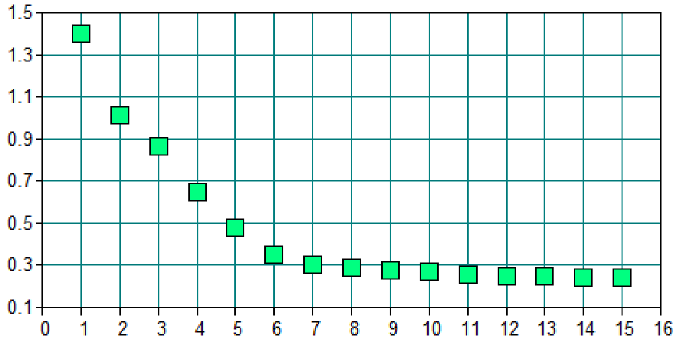

Figure 5. RMSEE as a function of PLS factor

Cross validation was done to check the calibrated values are shown in Fig 6. From the figure, it is seen that a comparison of scatter plots of predicted versus *NIR* true values for validation sets also showed that the *NIR* method gave close results. The developed *NIR* model thus may be able to accurately determine the protein content of rice samples.

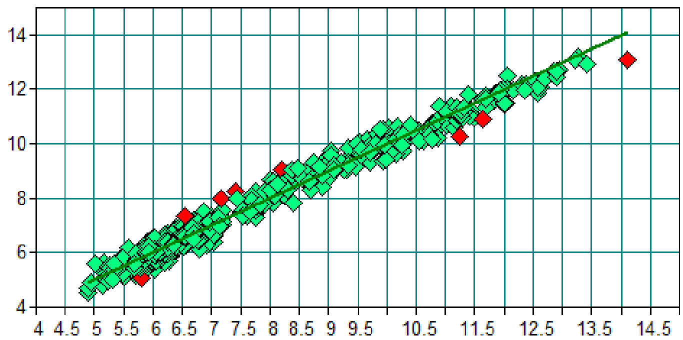

Figure 6. Cross validation of rice samples of actual and NIR predicted

Table 1. Range, mean and standard deviation of the crude protein content of rice samples

Chemical data	*Range*	*Mean*	*SD*
Calibration set (n=318)	*7,25-9,28*	*8,26*	*1,435*
Validation set (n=46)	*7,43-9,22*	*8,325*	*1,26*

SD - Standard deviation

Rice samples prepared were analyzed by *FT-NIR* spectroscopy and the previously developed chemometric method was applied to quantify protein content in rice samples. Results obtained from *FT-NIR* spectroscopy were compared with that of the laboratory methods are shown in Tab. 1. Results obtained from *FT-NIR* method were found to be approximately equal to Kjeldahl method.

CONCLUSIONS

The feasibility of measuring protein content in rice was investigated by using Fourier transform near-infrared (*FT-NIR*) spectroscopy with suitable chemometric techniques. Results of this study show that *NIR* spectroscopy could support chemical analysis in studying the quantitative assessment of rice. *NIR* is very promising tool to detect protein content in rice because, it is fast, nondestructive, accurate and reliable. Lower values of *RMSECV* and *RMSEE* and relatively higher values of R^2 showed that *NIR* spectroscopy has potential to predict the protein content of rice nondestructively with almost same accuracy as that of laboratory method. Furthermore, this developed model allowed for analyze the quality of rice at the time of procurement and fortnight observation of *FCI* (Food Corporation of India) and *CWC* (Centre Warehousing Corporation) with a very simple sample preparation method.

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RAZVOJ *PLS* MODELA ZA BRZO ODREĐIVANJE SADRŽAJA PROTEINA U PIRINČU UPOTREBOM FURIJEOVE TRANSFORMACIJE – BLISKA INFRACRVENA SPEKTROSKOPIJA

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Sažetak: Ovim istraživanjem je primenjena mogućnost upotrebe bliske infracrvene spektroskopije kao nedestruktivne analitičke metode za kvalitativnu i kvantitativnu procenu kvaliteta pirinča. *PLS* model je razvijen upotrebom pirinča sa različitim koncentracijama u bliskoj infracrvenoj oblasti (4.000–12.000 cm^{-1}). Razvijeni modeli su provereni tehnikom validacionog testa. *FT-NIR* spektroskopija sa hemometrijom, korišćenjem metoda *PLS*-prvog derivate plus vektroske normalizacije, može predvideti sadržaj proteina uskladištenog pirinča, sa koeficijentom korelacije (R^2) i rezidualnom prediktivnom devijacijom (*RPD*) od 0.98 i 7.21, redom. Mere greške, kao srednja kvadratna greška unakrsne validacije (*RMSECV*) i srednja kvadratna greška procene (*RMSEE*) bile su 0.28 i 0.25, redom. Razvijeni model je bio primenjen za procenu sadržaja protein u uzorku pirinča u roku od 15 sekundi. Postupak je dalje ocenjivan poređenjem sa mikro Kjeldahl metodom određivanja proteina. Ovi rezultati pokazuju da *NIR* spektroskopija može da podrži tradicionalne tehnike kvalitativne analize pirinča.

Ključne reči: *NIR spektroskopija, pirinač, protein, broj talasa, hemometrija, PLS model*

Prijavljen: *Submitted*:	08.04.2015.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	04.10.2015.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XL
Broj 4, 2015.
Strane: 35 - 46

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 35 - 46

UDK: 633.511

Originalni naučni rad
Original scientific paper

DESIGN AND DEVELOPMENT OF SELF PROPELLED WALK BEHIND FINGER TYPE COTTON STRIPPER

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***Abstract*:** In India, cotton is still picked manually by ladies pickers. Shortage of labor availability for cotton picking on farms results delayed picking of cotton crop and loss in term of cotton production. Commercially available cotton harvesters were tried for Indian varieties, but there were some issues regarding the cotton harvesting. Knowing the conditions of Indian farms, a conceptual design of self-propelled finger type cotton stripper is generated to pick/harvest the local high density and dwarf cotton varieties mechanically. In this self propelled finger type cotton stripper, the stripping fingers of 70 cm length were welded to the front part of engine frame at an angle of 21º. The width of the developed head was 64 cm. A rotating paddle/kicker, having a speed in the range of 120-250 min^{-1}, was designed to push the stripped materials (cotton bolls i.e. opened and closed along with sticks and burs) in to the collecting tank. A collecting drum/tank, having capacity 15-20 kg, was attached just behind the cotton stripper head for collecting stripped cotton materials. The developed prototype was evaluated on F-2383 and RCH-773 cotton varieties to observe its performance. The average value picking efficiency and picking capacity of developed cotton stripper was observed to be in the range of 76-80% and 135-325 $kg \cdot hr^{-1}$, respectively. The observed value of seed-cotton was observed in the range of 74-80% by using boll crusher/seed-cotton extractor, operational at Bathinda in Punjab.

Key words*: cotton crop, cotton stripper, crop attributes, machine performance attributes, boll crusher, seed-cotton output*

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The authors wish to acknowledge the financial assistance provided by the Department of Science and Technology, New Delhi. The work reported here was conducted as a part of the project entitled “Design and Development of Cotton Picking Head” funded by DST, New Delhi under project on “Centre for Precision and Conservation Farming Machinery”.

INTRODUCTION

Cotton, the most important fibre crop playing a key role in economic and social affairs of the world, continues to be acclaimed as 'King Fibre'. India is currently first in area, second in yarn production and third in raw cotton production in the world [2]. The cost of cotton production especially cost on labour during harvesting is excessively high, reducing the profit margin available to the farmer. Among all cotton crop production operations, cotton picking/harvesting is most difficult, tiresome and hard manual job. In advanced countries like USA, Brazil, Australia, cotton pickers and strippers are available for mechanical picking of cotton. Cotton pickers with different mechanisms such as Drum type spindle and Chain belt type spindle likewise cotton stripper with different mechanisms like finger type and brush type are available and working successfully in advanced countries.

Despite of these mechanical cotton harvesters available worldwide, the cotton picking is still done manually in most of the countries including India. The main reasons of not using these mechanical harvesters in India are their high cost, difficulty in operation due to small/marginal farms and indiscriminate type cotton varieties grown in India. In recent years it has been observed that labor shortage appear during the harvesting time of cotton results delayed picking and subsequent sowing of next crop. Knowing the conditions of Indian Farms and to overcome this situation of manual picking, efforts were made by different Institutions and Universities for the development of different types of cotton picker. Punjab Agricultural University (*PAU*), Ludhiana reported the development of pneumatic picker by using an industrial type vacuum cleaner for picking cotton in the field. Same type of study was done by *TNAU*, Coimbatore [3]. A tractor mounted vacuum type cotton picker was developed and evaluated by *PAU*, Ludhiana [1]. The picking efficiency of the developed picker was in the range of 70-75 percent, but the output of these machines was very low. Portable handheld type cotton picking machines were evaluated for different cotton varieties and found that there was no significant difference in the picking rate among chain, roller and manual picking at 5 percent level of significance. The average picking rate of both chain type and roller type cotton picking machines was measured to be 3.44 and 3.09 $kg \cdot hr^{-1}$, respectively for selected cotton varieties which was lesser as compared to manual picking rate i.e. 6.63 $kg \cdot hr^{-1}$. The percentage of trash content for both chain and roller type cotton pickers was also higher i.e. 11.52 and 10.44 percent as compared to trash content of 7.43 percent measured for cotton picked manually [6].

The idea of development of indigenous cotton stripper was conceptualised from the study, in which a Multiple Attributes Decision Making (*MADM*) technique was applied for selection and development of the mechanical cotton harvester, suitable for the local cotton varieties and agronomic practices [4]. It was observed that if relative ranking was given to the pertinent attributes then the best mechanical cotton harvesters for existing planting system prevalent in India and high density planting system was brush and finger type cotton strippers, respectively. But, the big challenge in development of cotton stripper was crop geometry, agronomic practices for cultivation of crop and seed-cotton extraction from the cotton bolls harvested with boll shells and cleaning prior to ginning. To view these earlier made efforts, a self propelled walk behind type cotton stripper was developed due to its low cost and easy operation as compared to other mechanical cotton picking machine. Because, the developed modal required dwarf cotton varieties and special planting system i.e. High Density Planting System (*HDPS*) for its field operation. Hence, the selected dwarf cotton varieties were cultivated with modified agronomic practices to obtain the short plant height and high plant population required for cotton stripper. To extract the seed-cotton from the stripped/harvested material, a boll crusher cum cotton extractor, presently operational at Bathinda, Punjab was considered due to its higher efficiency and capacity.

MATERIAL AND METHODS

A brief description of design and development of indigenous cotton stripper and other related processes are given under this section.

Design and development of self propelled walk behind finger type cotton stripper. A conceptual design of finger type cotton stripper was generated by keeping in view the local cotton varieties grown in small/marginal farm. Machine should be of simple design, lower capital cost, lower repairing and maintenance cost and lesser moving components. The physical prototype of finger type cotton stripper was designed to pick/harvest the local high density and dwarf cotton varieties mechanically. The idea of physical development of self propelled cotton stripper was derived from the study conducted by Tupper G R in 1966 [7]. An experimental cotton stripper was designed and built by the Arkansas Agricultural Experiment Station for harvesting either broadcast or narrow row cotton. Burr cotton was stripped from the plant with a series of stationery teeth approximately 66 cm in length and spaced approximately 1.6 cm between teeth. In operating position, the stripper teeth were inclined approximately 15 degrees in respect to the ground, with the angle of inclination being changeable with hydraulic controls.

A self propelled walk behind finger type cotton stripper was developed by mounting the designed cotton stripper header on the self propelled power tiller having an engine of 3.6 kW. Cotton stripper header was developed by selecting the suitable specifications of stripping fingers, kicker/paddle, belt-pulley arrangement and material collecting tank. In this self propelled finger type cotton stripper, the stripping fingers of 70 cm length were welded to the front part of engine frame at an angle of 21º. The width of the developed header was 64 cm. A rotating paddle/kicker, having a speed in the range of 120 - 250 min^{-1}, was designed to push the stripped materials (cotton bolls i.e. opened and closed along with sticks and burs) in to the collecting tank. A collecting drum/tank, having capacity 15-20 kg, was attached behind the cotton stripper header for collecting stripped cotton materials. Fig. 1 shows the line diagrams of top and side views of cotton stripper and Table 1 shows the brief specifications of developed prototype of self propelled cotton stripper.

The designed cotton stripper works on the principle that when the cotton stripper will move through the cotton field due to its forward motion, inclined fingers will strip the cotton bolls with burs including green bolls, sticks and leaves from the plants and rest of the plant will remain in its position in the field. Cotton bolls with shells/burs will be stripped from the plants with the help of a series of stationery inclined fingers having a narrow gap among the fingers. The stripped materials will be moved upward to the inclined fingers with the force of next group of plants being stripped. A kicker/paddle mounted at the rear-side of the fingers will help to convey the stripped materials to the collecting tank. Fig. 2 shows the operational view of self propelled cotton stripper in the field before and after the harvesting.

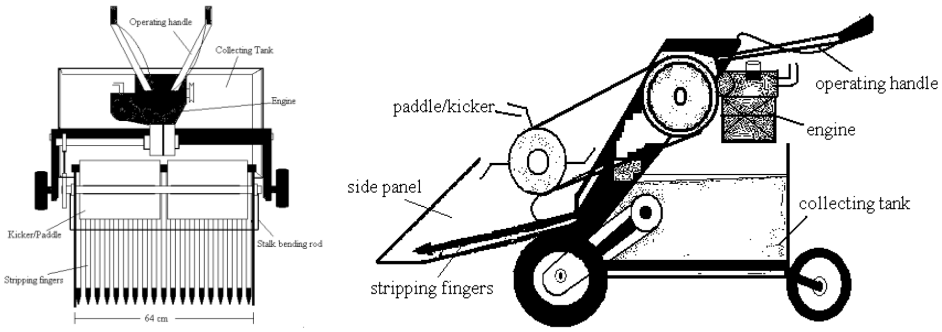

Figure 1. Top and side view of self propelled finger type cotton stripper

Table 1. Technical specifications of stripper

No	*Attribute*	*Range*
1	*Engine power (kW)*	*3.6*
2	*Forward speed range (km·hr^{-1})*	*2.0 - 4.5*
3	*Engine speed (min^{-1})*	*1500*
4	*Width of stripper head (cm)*	*65*
5	*Number of stripping fingers*	*19*
6	*Length of stripping fingers (cm)*	*70*
7	*Thickness of stripping fingers (cm)*	*1.8*
8	*Gap between two fingers (cm)*	*1.5*
9	*Slope angle (with horizontal) of stripper head*	*21^0*
10	*Paddle/kicker speed (min^{-1})*	*120-250*
11	*Capacity of collecting tank (kg)*	*15-20*

Figure 2. Operational view of cotton stripper in the field before and after harvesting of crop

Boll crusher cum seed-cotton extractor. The harvested material having leaves, sticks, and cotton with outer shells (bur) need to be removed and separated to obtain seed-cotton. To remove the outer shells from cotton bolls, a boll crusher/seed-cotton extractor (Millennium Model), developed by a local manufacturer and operational at Bathinda, Punjab, was used. Fig. 3 shows the self explanatory line diagram of boll crusher currently available in Punjab. The stripped material was fed manually to the boll crusher with the help of air suction unit. The air suction blower created suction to convey the feeding material to serrated drum/cylinder. The working principle of boll crusher cum seed-cotton extractor is when cotton bolls come into the contact with cylinder (drum) and concave assembly than the cotton burs are removed with the rubbing action between the cylinder and concave and cotton fibre sticks to the drum of having the serrated surface. The seed-cotton wrapped on the drum was removed with the help of brush roller rotating in the opposite direction to the serrated drum with the speed of 1440 min^{-1}. The seed-cotton separated from the shells and other foreign material was collected from the rear side of the machine known as seed-cotton outlet. The foreign material includes burs/shells, leaves, sticks, dust particles etc. was removed with the help of screw conveyor called trash outlet. Fig. 3 and Tab. 2 show the line diagram and operational view of boll crusher/seed-cotton extractor and its technical specifications.

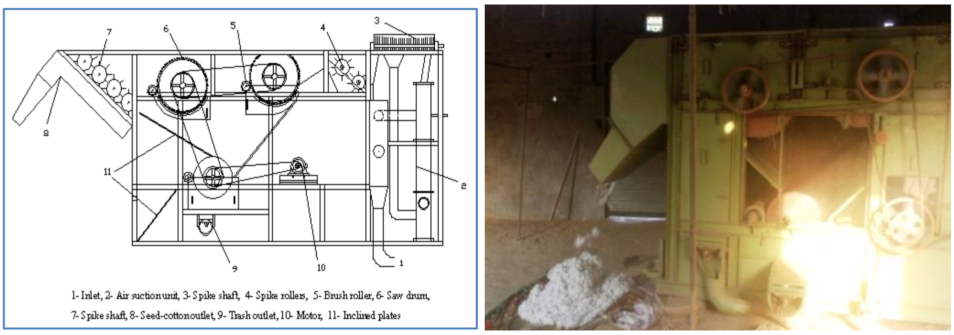

Figure 3. Line diagram and operational view of boll crusher/seed cotton extractor

Table 2. Technical specifications of boll crusher/seed-cotton extractor

S. No.	Attributes		Observations
1	Total power requirement for boll crusher		11.2 kW
2	Blower power		3.7 kW
3	Blower (min^{-1})		1440
4	Drum type		Serrated (saw) drum
5	Speed of rotating drums (min^{-1})	Drum 1	360
		Drum 2	360
		Drum 3	160
6	Speed of small/brush roller (min^{-1})		1440
7	Speed of rotating spikes (min^{-1})		600

The power requirement for the operation of boll crusher is 11.2 kW. Two electrical motors of 3.7 kW each and an air-suction blower operated with 3.7 kW motor are used for the boll crusher operations. The saw drums (large drums) operated with installed motors rotates with 360 min^{-1} (upper drums) and 160 min^{-1} (lower drum) respectively.

The parameters like lint turnout and trash content can be calculated during the cotton extracting operation.

Agronomic practices. Special crop geometry and suitable agronomic practices are required for growing the cotton varieties so that the developed cotton stripper could be performed well in the field experiments. The field experiments for evaluation of cotton stripper were conducted at Research Farms of Punjab Agricultural University (*PAU*), Ludhiana and Regional Research Station (*RRS*), Bathinda. Cotton varieties i.e. F-2383 and RCH-773 were identified for experiments due to its suitable characteristics like short height, less canopy and less vegetation. The crop was sown by adopting a new planting system i.e. High Density Planting System (*HDPS*) at 45x30 and 67.5x30 cm spacing instead of 67.5x60.0 cm recommended by the university for selected cotton varieties. The crop was harvested about 188-198 days after sowing. Figure 4 shows the standing view of F-2383 and RCH-773 cotton varieties in the field.

Figure 4. Crop view of F-2383 and RCH-773 cotton varieties

Defoliants are chemicals or methods of treatment that cause only the leaves of a plant to abscise, or fall off. Defoliants are applied to cotton to improve and facilitate mechanical harvest [6]. Defoliant was sprayed before 20 days of harvesting to improve the harvesting efficiency of cotton harvester. It helps to shed the leaves of plants and to make the green bolls mature early so that the harvesting operation could be made easy and effective. In present experiment, 2-*Chloroethyl-phosphonic acid* (Ethrel) defoliant was used to fall off the leaves of cotton plant to improve and facilitate mechanical harvest. The defoliant was sprayed with the help of knapsack sprayer and self propelled electrostatic sprayer.

Measurement of trash content in seed-cotton. Cotton stripper strips the cotton crop which includes opened/closed bolls, leaves, sticks and other trash contents. Materials like burs, sticks were removed with the help of boll crusher cum seed-cotton extractor during the cotton extracting operation. To remove the trash entangled with seed-cotton extracted from the boll crusher, a commercially available Texaco trash analyzer Make (Texaco Engineering, Model: Texaco) was used. Trash like entangled leaves with cotton, dust particles mixed with cotton fibre were removed with the help of trash analyzer. Trash analyzer consists of the serrated drum, air-vacuum pump, heavy trash chamber, lint collector, macro and micro dust plates. For measuring the trash content in the seed-cotton, the lint was separated from the seed. Then the weighted (known) sample was fed into the trash analyzer having articulated feeding claws and the weight of lint turnout and trash content were measured separately to obtain the percentage of trash content from the sample during the machine operation.

RESULTS AND DISCUSSION

Crop geometry and characteristics. Tab. 3 shows the cotton crop characteristics for F-2383 and RCH-773 cotton varieties, sown at different plant spacing and its statistical analysis using Completely Randomised Design (*CRD*). Plant height of variety F-2383 sown at closer row to row spacing of 45 cm was significantly shorter than plant height at row to row spacing of 67.5 cm at same location. Plant height of F-2383 sown at Bathinda was significantly shorter as compared to plant height of same variety sown at Ludhiana with same plant spacing. The change in plant height was due to soil and climatic difference at different locations. Plant height of RCH-773 was significantly longer i.e. 92 cm than the height of F-2383 i.e. 83 cm sown at same location. The plant width (canopy) across row of F-2383 was significantly lesser i.e. 56.6 cm sown at row to row spacing of 45 cm than the plant canopy of same variety i.e. 68.4 cm sown at 67.5 row to row spacing. Plant canopy for variety F-2383 sown at Ludhiana was significantly higher i.e. 68.4 as compared to plant canopy i.e. 54.2 cm of same variety, but sown at different location. Similarly, the plant canopy of RCH-773 was significantly more i.e. 70.2 cm as compared to plant canopy i.e. 54.2 cm of F-2383 sown at same spacing.

Table 3. Crop characteristics data

S.N.	*Attribute*	*Average values of observed data*				*CD (5%)*
1	*Field location*	*PAU, Ludhiana*		*RRS, Bathinda*		
2	*Cotton variety*	*F-2383*	*F-2383*	*F-2383*	*RCH-773*	-
3	*Plant spacing (cm)*	*45x30*	*67.5x30*	*67.5x30*	*67.5x30*	-
4	*Plant height (cm)*	*75.6*^{a}	*91.8*^{b}	*83.0*^{c}	*92.0*^{b}	*6.00*
5	*Plant canopy across row (cm)*	*56.6*^{a}	*68.4*^{b}	*54.2*^{a}	*70.2*^{b}	*4.30*
6	*Height of lower boll (cm)*	*28.2*^{a}	*27.6*^{a}	*19.2*^{b}	*23.4*^{c}	*3.82*
7	*Height of upper boll (cm)*	*68.6*^{a}	*68.0*^{a}	*77.0*^{b}	*83.0*^{c}	*4.70*
8	*No. of opened bolls*	*22.0*^{a}	*21.0*^{a}	*27.0*^{b}	*30.0*^{c}	*2.50*
9	*No. of green/unopened bolls*	*3.0**	*3.0**	*2.0**	*2.0**	*NS*
10	*Crop yield* ($kg \cdot ha^{-1}$)	*595.0*^{a}	*690.0*^{b}	*715.0*^{c}	*1395.0*^{d}	*16.00*

From Tab. 3, it was found that the height of lower and upper boll of F-2383 sown at same location but at different spacing showed no significant difference with each other. The height of lower boll was significantly more for RCH-773 than F-2383 sown at same location. Similarly, the height of upper boll of variety RCH-773 was significantly more than F-2383 sown at same spacing and same location. The change in height of upper and lower boll of RCH-773 was due to overall height of plants. Number of opened bolls was significantly more i.e. 30 for RCH-773 as compared to F-2383, having 27 opened bolls at the same location for same plant spacing. The number of opened bolls for F-2383 at same location but at different spacing was not significantly different with each other.

There was no significant different for the green/unopened bolls for both the varieties. Crop yield of variety F-2383 sown at 67.5x30 was significantly more than crop yield of same variety sown at 45x30 cm spacing at same location. Crop yield of RCH-773 was significantly higher i.e. 1395 $kg \cdot ha^{-1}$ as compared to crop yield i.e. 715 $kg \cdot ha^{-1}$ of F-2383 sown at same spacing and same location. The difference in yield may be due to big size results in more weight of cotton bolls.

Field performance of self-propelled cotton stripper. Tab. 4 show field performance data of the developed cotton stripper. The picking efficiency of cotton stripper was observed to be non significant for F-2383, sown at different spacing at PAU Farm. The picking efficiency for RCH-773 was observed to be non significant with F-2383, sown at same location. The average value of picking efficiency was observed to be 78.45 percent. The observed values of stalk and ground losses for F-2383 were not significantly different with each other. There was no significant difference in ground losses between RCH-773 and F-2383 sown at same spacing and same location. The average value of losses was observed to be 21.55 percent. The main reason behind the stalk loss was the height of the cotton bolls attached to the lower part of the plants at the average height of less than 25 cm which did not come in to the contact of the stripping fingers which were mounted at the front part of engine with ground clearance more than 25 cm. The reason of the ground loss may be due to vibration of the engine and positioning of the collecting tank. Fig. 5 shows the graphical representation of the stalk and ground losses observed during the performance of the cotton stripper. In the conducted experiments for picking capacity of cotton stripper, the observed value of picking capacity for F-2383 was significantly lower i.e. 135.3 $kg \cdot h^{-1}$, as compared to picking capacity i.e. 157.8 $kg \cdot h^{-1}$, for same variety, sown at 67.5 and 45 cm row spacing. Picking capacity for RCH-773 was found to be significantly higher i.e. 325 $kg \cdot h^{-1}$ as compared to capacity i.e. 156.3 for F-2383 sown at same spacing and same location. There was no significant difference among the values of field capacity for both varieties with an average value of 0.118 $ha \cdot h^{-1}$.

Table 4. Field evaluation of self propelled walk behind type cotton stripper

S.N.	*Attribute*	*Observations and performance data of cotton stripper*				*CD (5%)*
1	*Field location*	*PAU, Ludhiana*		*RRS, Bathinda*		
2	*Cotton variety*	*F-2383*	*F-2383*	*F-2383*	*RCH-773*	*-*
3	*Plant spacing (cm)*	*45x30*	*67.5x30*	*67.5x30*	*67.5x30*	*-*
4	*Material harvested ($kg \cdot ha^{-1}$)*	*1140.0*	*1318.5*	*1366.6*	*2750.0*	*-*
5	*Picking efficiency (%)*	*78.8*	*79.8*	*76.4*	*78.8*	*NS (78.45)*
6	*Losses (stalk and ground) (%)*	*21.2*	*20.2*	*23.6*	*21.2*	*NS (21.55)*
7	*Picking capacity ($kg \cdot ha^{-1}$)*	*135.3^a*	*157.8^b*	*156.3^b*	*325.0^c*	*7.34*
8	*Field capacity ($kg \cdot ha^{-1}$)*	*0.12*	*0.12*	*0.11*	*0.12*	*NS (0.118)*

Performance of boll crusher/seed-cotton extractor. The material stripped by the cotton stripper was conveyed to the boll crusher. The seed-cotton output though boll crusher for material stripped by cotton stripper is shown in Tab. 5. In the experiments conducted for F-2383, stripped material with an average weight of 9.3 kg was fed to boll crusher to obtain the seed-cotton and material waste (burs, leaves, sticks etc.). The average weight of seed-cotton output was observed to be 7.23 shared the 77.4 percent of total fed material. The average weight of material waste was found to be 2.11 kg shared 22.6 percent of the total material. Similarly, in the experiments for RCH-773, with an average 7.98 kg weight of stripped material was fed to boll crusher to obtain the seed-cotton and material waste (burs, leaves, sticks etc.). The average weight of seed-cotton output was observed to be 6.00 kg shared 75.75 percent of total fed material. The average weight of material waste was found to be 1.94 kg shared 24.25 percent of the total stripped material.

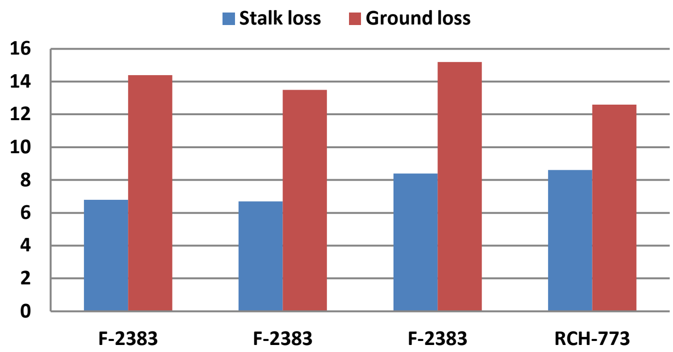

Figure 5. Graphical representation of stalk and ground losses at different locations

Table 5. Seed-cotton output though boll crusher for material stripped by cotton stripper

Cotton variety	*Stripped material weight*	*Seed-cotton weight*		*Material waste (burs, leaves, sticks etc.)*	
	(kg)	*(kg)*	*(%)*	*(kg)*	*(%)*
F-2383 (PAU, Ldh)	*11.000*	*8.60*	*78.2*	*2.40*	*21.8*
	9.000	*6.84*	*76.0*	*2.16*	*24.0*
	8.000	*6.24*	*78.0*	*1.76*	*22.0*
	9.300	*7.23*	*77.4*	*2.11*	*22.6*
RCH-773 (RRS, Bathinda)	*8.100*	*5.93*	*73.2*	*2.17*	*26.8*
	7.850	*6.15*	*78.3*	*1.70*	*21.7*
	7.980	*6.00*	*75.7*	*1.94*	*24.2*

Table 6. Trash analysis of harvested cotton

Picking type	*S.N.*	*Sample weight (g)*	*Gin/lint turnout (g)*	*Seed weight (g)*	*Trash content (g)*	*Trash content (%)*
Cotton stripper	*1*	*100*	*31.5*	*40.0*	*28.5*	*28.5*
	2	*100*	*29.6*	*42.6*	*27.8*	*27.8*
	3	*100*	*28.7*	*42.1*	*29.2*	*29.2*
	Avg.	*100*	*29.9*	*41.5*	*28.5*	*28.5*
Manual	*4*	*100*	*33.5*	*41.0*	*7.5*	*7.4*

Trash content. It was observed that the trash content in cotton picking with stripper was higher i.e. in the range of 27-30 % as compared to the manual picking i.e. 7.5

percent, respectively. Fig. 6 and Tab. 6 show the cotton sample before and after experiments with trash analyzer and observed data during the experiments.

Figure 6. Cotton sample before and after trash analyzing operation

Quantitative observations of harvested seed-cotton. Tab. 7 shows the calculated percentage values of the seed-cotton obtain from the harvested material and gin turnout of both cotton varieties. For F-2383 variety, the observed value of seed-cotton was found to be 77.4 % containing foreign material (trash) in the form of leaves, small sticks, dust particle etc. The measured value of seed-cotton with trash was 75.8% for RCH-773. The percentage of clean seed cotton for F-2383 was observed to be 55.1% and 53.9% for RCH-773 variety. The values of gin turnout for both varieties were observed to be 25.0 and 31.6%, respectively.

Table 7. Percentage Values of Seed-Cotton and Gin Turnout for F-2383 and RCH-773

S.N.	*Parameters*	*Observations of seed-cotton*			
		F-2383		*RCH-773*	
		(kg·ha^{-1})	*(%)*	*(kg·ha^{-1})*	*(%)*
1	*Material stripped by cotton stripper*	*1275.0*	*100.0*	*2750.0*	*100.0*
2	*Seed-cotton + trash content after boll crushing*	*986.9*	*77.4*	*2084.5*	*75.8*
3	*Cleaned seed-cotton*	*702.7*	*55.1*	*1484.2*	*53.9*
4	*Gin turnout*	*175.7*	*25.0*	*469.0*	*31.6*

Labour requirement. The main cause of adopting the mechanical cotton harvester was to reduce the labor requirement (man-h·ha^{-1}) of cotton picking. During the field operation of cotton stripper, It was found that the labor requirement for picking the cotton bolls with stripper was measured to be 08-10 man-h/ha, lesser as compared to the labor requirement for manual picking of cotton bolls with burs i.e. 100-120 man-h·ha^{-1}. Labor requirement for combine operation of machine picking of cotton bolls and boll crusher was also lesser i.e. 15-20 man-h·ha^{-1} as compared to the labor requirement for combine operation of manual picking of cotton bolls and boll crusher i.e. 125-130 man-h·ha^{-1} for extracting the seed-cotton. Labor requirement for manual picking of seed-cotton was measured in the range of 400-450 man-h·ha^{-1}. Labor requirement of cotton picking was lesser i.e. 90.9% in the case of machine picking of cotton bolls as compared to the manual picking of cotton bolls with burs. Similarly, the saving of labor in manual picking and machine picking of boll/boll crusher for seed-cotton extraction was 70.1 and 96.0%, respectively as compared to manual picking of seed-cotton (Tab. 8).

Table 8. Comparison of labor requirement

S. N.	*Cotton picking methods*	*Labour requirement (man-h·ha^{-1})*	*Saving (%)*
1	*Manual picking of seed-cotton*	*400 - 450*	*-*
2	*Manual picking of cotton bolls along with burs*	*100 - 120*	*-*
3	*Machine picking of cotton bolls along with burs*	*8 - 10*	*90.9*
4	*Manual picking of bolls along with burs + using boll crusher for seed-cotton extraction*	*125 - 130*	*70.1*
5	*Machine picking of bolls along with burs + using boll crusher for seed-cotton extraction*	*15 - 20*	*96.0*

CONCLUSIONS

The field performance of developed stripper was done on F-2383 and RCH-773 cotton varieties to observe the picking efficiency and picking capacity. From the conducted experiments, it was concluded that:

- Plant height of variety F-2383 sown at closer row to row spacing of 45 cm was significantly shorter than plant height at row to row spacing of 67.5 cm at same location and plant height of RCH-773 was significantly longer i.e. 92 cm than the height of F-2383 i.e. 83 cm sown at same location.
- Plant canopy of RCH-773 was significantly more i.e. 70.2 cm as compared to plant canopy i.e. 54.2 cm of F-2383 sown at same spacing.
- Crop yield of RCH-773 was significantly higher i.e. 1395 kg·ha^{-1} as compared to crop yield i.e. 715 kg·ha^{-1} of F-2383 sown at same spacing and same location. The difference in yield was due to big size and more weight of cotton bolls.
- Picking efficiency of developed cotton stripper was observed in the range of 75-80%
- Picking capacity of cotton stripper was observed in the range of 135 to 325 kg·ha^{-1}.
- Seed- cotton output through the boll crusher cum seed-cotton extractor was found to be 74 to 79%.
- Trash content in cotton picking with stripper was higher i.e. in the range of 25-30 % as compared to the manual picking i.e. 7.5 percent, respectively.
- Labor requirement during cotton picking by stripper was in the range of 8.30-8.75 man-h·ha^{-1} and saving of labor in mechanical cotton picking was 90.9% as compared to the manual picking.

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KONSTRUKCIJA I RAZVOJ BERAČA PAMUKA SA RUČNIM POGONOM

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***Sažetak*:** U Indiji se još uvek pamuk bere ručno. Nedostatak radne snage dovodi do odloženog branja i gubitaka u proizvodnji. Berači koji su dostupni na tržištu su probani sa indijskim sortama, ali bilo je problema. Poznajući uslove na farmama u Indiji, razvijen je berač sa prstima na ručni pogon za branje domaćih sorti pamuka. Kod ove konstrukcije prsti dužine 70 cm su zavareni na prednji deo rama mašine pod uglom od 21°. Širina glave je 64 cm. Rotacione pedale rotiraju sa 120-250 min^{-1} i guraju ubranu masu (čaure sa peteljkama) u sabirni sanduk kapaciteta 15-20 kg. Sanduk je postavljen odmah iza glave berača. Ovaj prototip je testiran na sortama F-2383 i RCH-773. Srednja efikasnost i kapacitet branja iznosili su 76-80% i 135-325 $kg \cdot hr^{-1}$, redom. Istresanje semena je iznosilo 74-80% primenom drobilice čaura.

***Ključne reči*:** *usev pamuka, berač pamuka, osobine useva, karakteristike mašine, drobilica čaura, izlaz semena*

Prijavljen: *Submitted*:	08.04.2015.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	12.10.2015.

Univerzitet u Beogradu Poljoprivredni fakultet Institut za poljoprivrednu tehniku Naučni časopis ***POLJOPRIVREDNA TEHNIKA*** Godina XL Broj 4, 2015. Strane: 47 - 56		University of Belgrade Faculty of Agriculture Institute of Agricultural Engineering Scientific Journal ***AGRICULTURAL ENGINEERING*** Year XL No. 4, 2015. pp: 47 - 56

UDK: 633.11

Originalni naučni rad
Original scientific paper

DEVELOPMENT AND STANDARDIZATION OF NITROGEN (LIQUID UREA) APPLICATION METERING MECHANISM FOR POINT INJECTION NITROGEN APPLICATOR

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Abstract: The existing method of broadcasting urea on straw mulched direct seeded wheat crop is susceptible to nitrogen losses. Nitrogen (liquid urea) applicator could be used to forestall the hazards of nitrogen loss and a metering mechanism for nitrogen (liquid urea) is currently not available. Hence, a nitrogen (liquid urea) metering mechanism was developed and tested in the laboratory. The operating pressure and peripheral speed of metering system were found to have significant effect on the discharge rate of metering mechanism. The discharge rate of the metering system was directly correlated with operating pressure and indirectly correlated with peripheral speed of the metering system. Based on the performance parameters, a peripheral speed of 0.70 $m \cdot s^{-1}$ (forward speed of 2.5 $km \cdot h^{-1}$), operating pressure of 3 $kg \cdot cm^{-2}$ and 2.095 $l \cdot ha^{-1}$ application rate of urea solution were selected for field operation of nitrogen (liquid urea) applicator. The outcome of this study will encourage the use of point injected nitrogen (liquid urea) applicator on straw mulched crops.

Key words*: discharge rate, metering mechanism, nitrogen (liquid urea) application, peripheral speed, operating pressure*

INTRODUCTION

Rice- wheat constitutes the most productive cropping system in India, covering approximately 10–12 million hectares. Punjab contributes 40–50% of the rice and 50–70% of the wheat in the central pool, from only 1.5% of the land [5].The scarcity of

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labor and time has led to the adoption of mechanized farming in highly intensive rice-wheat system in the state. This mechanization has been achieved by the developing various machineries based on crop and need [3]. The area under combine harvested rice and wheat in Punjab during 2008-09 was about 91 % and 82 %, respectively of the total area [10]. After combine harvesting, the rice residues comprise standing stubbles, usually 30–60 cm high, plus a substantial quantity of loose straw. The loose residues interfere with tillage and seeding operation for the next crop. More than 90% of the of rice stubble in Punjab are burnt each year, resulting in thick smoke blanketing the region [8]. The burning also results in the loss of nutrients and organic matter from the soil. Incorporation of rice residue requires nearly five or more tillage operations. Keeping in view these aspects, a machine ('Happy Seeder') was developed by Punjab Agricultural University, Ludhiana, which could direct drill wheat into heavy rice residue loads, without burning in a single operation. The yield of wheat sown into rice residues using the 'Happy Seeder' was comparable to or higher than yields with conventional sowing [7].

In high residue no-till farming, efficient nitrogen fertilizer application remains a challenge because of slower nitrogen mineralization, greater nitrogen immobilization and higher de-nitrification and ammonia volatilization losses. The presence of crop residues on the soil surface containing urea increases the potential for ammonia volatilization in no-till systems [1]. About 25% of the nitrogen applied as urea is lost via ammonia volatilization [6].

Reducing fertilizer nitrogen contact with the straw mulch by placing it into the soil surface can reduce nitrogen immobilization and ammonia volatilization which can increase grain yield, plant N uptake and nitrogen use efficiency [2, 10, 4]. Therefore, a need was felt to have a nitrogen (liquid urea) applicator that can apply nitrogen fertilizer (liquid urea) into the soil surface without disturbing straw mulch in directly sown combine harvested wheat [9]. For the development of such nitrogen applicator, the main component i.e. nitrogen (liquid urea) metering mechanism is required. Fertilizer metering mechanisms for granular fertilizers are commercially available. So, there is a need to develop a metering mechanism for proper and efficient application of nitrogen (liquid urea) in straw mulched crops.

MATERIAL AND METHODS

Description of the nitrogen (liquid urea) metering mechanism. A nitrogen (liquid urea) metering mechanism to be used for point injected nitrogen applicator [9] was developed at Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana, India. Before developing actual working component, computer aided conceptual view of component was made to give exact idea for fabrication (Fig. 1). The calibration and evaluation studies were conducted in the research laboratory of Punjab Agricultural University, Ludhiana during 2012-13.

It consists of spoke wheel, distribution hub, injectors and cut-off mechanism (Fig. 2). The liquid urea solution is supplied to the spoke wheel with pressure with the help of a piston type double cylinder pump with a pressure regulator. All the injectors attached to the distributor hub are under pressure of nitrogen (liquid urea). As and when the injector touches the soil surface, a specially designed stationery cam actuated crank lever mechanism which opens the flow control valve of that injector to inject the nitrogen (liquid urea) beneath the straw mulch into the soil surface. The brief specifications are given in Tab. 1 and description of major components is given below.

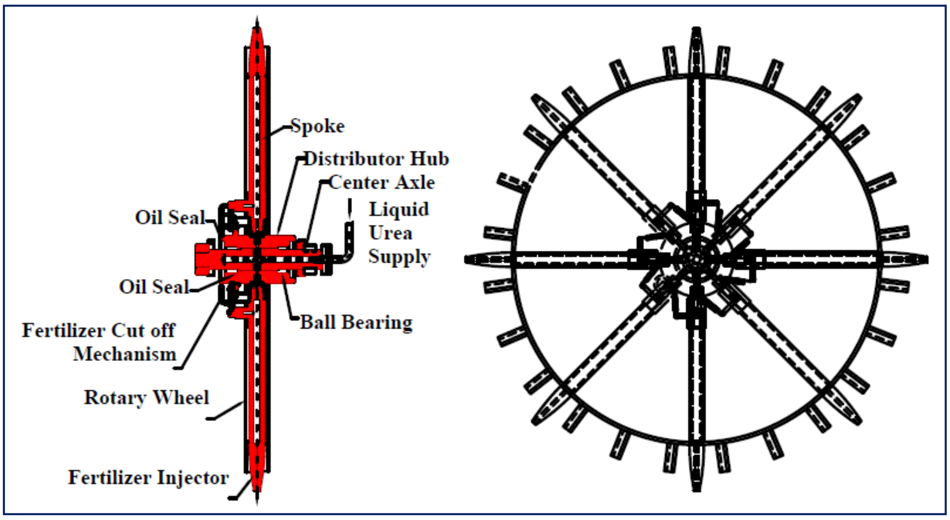

Figure1. Computer aided conceptual view of nitrogen (liquid urea) metering mechanism

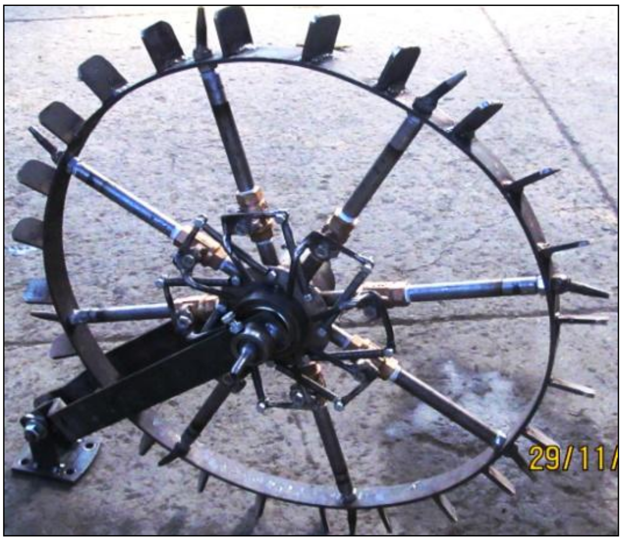

Figure 2. View of developed nitrogen (liquid urea) metering mechanism

Distribution Hub. The distribution hub acts as a reservoir in which liquid urea is supplied longitudinally from one side and exit tangentially out of eight spokes mounted on the periphery of the distribution hub. A distribution hub is made with a mild steel cylinder of 5 mm thickness, 50 mm diameter and 125 mm length. Eight numbers of hollow spokes are extended radially outward from the circumference of the distribution hub. The distribution hub includes an axle, two ball bearings and a cylindrically shaped housing with an axially aligned open centre portion in which the axle bearings are secured. Rubber seals are provided on inner side of the bearings to make it leakage free. The axle has two radial hole of 6 mm diameter on its periphery for supply of liquid urea to different spokes of the wheel. A 40 mm hollow pressure pipe has been used to serve as an axle. The axle positions the two ball bearings to permit rotational movement of the distribution hub with respect to the axle. The closed inner end and open end of the axle is connected to the liquid urea supply line. The axle surface is stair-stepped outwardly to enlarge its diameter at the centre for proper fitting of ball bearings with seal on both ends and the space between two bearings acted as housing for liquid urea.

Injector. Injectors are made from high carbon steel rod of ∅ 12.5 mm and provide a cone shape at one end for easy penetration in straw mulch mat and soil surface. The injectors are fitted in slanting position with the spoke to avoid entangle of straw mulch. A bore of ∅ 3 mm is bored inside the injector. The other end of the injectors with external threads is fitted inside spoke of ∅ 9.5 mm.

Table 1. Specification of the developed nitrogen (liquid urea) metering mechanism

	Components	*Specifications*
1, Distribution hub		
i)	*Shape and size*	*Cylindrical, 50 x 125 mm*
ii)	*No. of spoke on hub*	*8*
2. Fertilizer injector		
i)	*Type*	*Cone shaped*
ii)	*Length of injector*	*60 mm*
iii)	*Orifice diameter of injector*	*3 mm*
3. Nitrogen (liquid urea) metering mechanism		
i)	*Type*	*Rotary valve metering*
ii)	*Diameter of spoke*	*9.5 mm*
4. Cut-off mechanism		
i)	*Type*	*Cam actuated flow control valve*
ii)	*Size of valve*	*¾ inch*

Cut-off mechanism. The nitrogen (liquid urea) cut-off mechanism consists of an inline mounted flow control valve to regulate the liquid urea flow between distributor and injector. Each flow control valve fitted in spoke assembly is provided with independent cutoff lever. A specially designed crank lever regulates the opening and closing of flow control valve. The load arm of the lever is attached with a helical tension spring; which kept the flow control valve in closed position. The effort arm of the crank lever is actuated by a stationery cylindrical cam fitted tangentially on a plate with the rotary wheel. With the rotation of rotary wheel, the effort arm of the lever strikes with the cam and is pushed back; which results into the opening of the flow control valve. As the lever arm passes the cam, the flow control valve comes to its closed position by the tension of the spring and liquid urea supply to the injectors is disconnected.

Laboratory evaluation. The metering mechanism was calibrated and evaluated in the laboratory conditions for discharge rate, application rate, spread diameter of wetted soil, depth of injection, discharge variation within injectors and discharge variation with simultaneously injectors opening. The standard test rig with variable drive was used to test the nitrogen (liquid urea) metering mechanism. The operating pressure of liquid urea was monitored by an engine operated piston type pump. A stationery view of pump with pressure regulator of the experiment set up is shown in Fig. 3. The metering mechanism was evaluated for three levels of operating pressures (2.5, 3.0 and 3.5 $kg·cm^{-2}$) and three levels of peripheral speed (0.56, 0.70 and 0.83 $m·s^{-1}$). Rectangular trays were used to collect the liquid urea discharged from each injector for one minute duration. Application rate of liquid urea ($l·ha^{-1}$) was calculated from discharge rate and assuming row to row spacing of 40 cm and perimeter of injectors. Parameters like depth of injection and spread diameter of wetted soil were measured by operating the nitrogen applicator in field cum lab condition. Based on variable parameters, the metering mechanism was standardized for operating pressure and peripheral speed so that desired application rate could be maintained.

Figure 3. Laboratory evaluation of nitrogen (liquid urea) metering mechanism

RESULTS AND DISCUSSION

Effect of operating pressure and peripheral speed of metering system on discharge rate. The effects of operating pressure and peripheral speed on the discharge rate of the metering system was significant at 5% level of significance (Tab. 2). Discharge rate from a particular injector increased with the increase in operating pressure and decreased with increase in peripheral speed. Increase in operating pressure results in increase in flow speed of the liquid through orifice of the cut-off valve which results in increase in discharge rate whereas with increase in peripheral speed, the time for opening of the flow control valve decreases resulting in lesser discharge. The interaction of both the variables was also significant at probability level of 0.05.

Effect of operating pressure and peripheral speed of metering system on application rate. The effects of operating pressure and peripheral speed on the application rate was significant at 5% level of significance (Tab. 2). Application rate increased with the increase in operating pressure and decreased with increase in peripheral speed. The average application rate of 2095.4 $l \cdot ha^{-1}$, which was closest to liquid urea application rate used in the design of metering mechanism, was obtained at peripheral speed of 0.70 $m \cdot s^{-1}$ with operating pressure of 3 $kg \cdot cm^{-2}$. The interaction of both the variables was also significant at probability level of 0.05.

Effect of operating pressure and peripheral speed of metering system on Spread diameter. The effect of operating pressure and peripheral speed on spread diameter of wetted soil was significant at 5% level of significance (Tab. 2). Spread diameter increased with the increase in operating pressure and decreased with increase in peripheral speed. The highest average spread diameter of wetted soil (170.63 mm) was obtained at peripheral speed of 0.56 $m \cdot s^{-1}$ and operating pressure of 3.5 $kg \cdot cm^{-2}$ while the lowest average spread diameter of wetted soil (99.07 mm) was obtained at peripheral speed of 0.83 $m \cdot s^{-1}$ and operating pressure of 2.5 $kg \cdot cm^{-2}$. The interaction of both the variables was also significant at probability level of 0.05.

Table 2. Effect of peripheral speed and operating pressure on the discharge rate, application rate, spread diameter and depth of injection

Independent variables		*Dependent variables*			
Operating pressure (A) ($kg \cdot cm^{-2}$)	*Peripheral speed (B) ($m \cdot s^{-1}$)*	*Average discharge rate ($ml \cdot min^{-1}$)*	*Average application rate ($l \cdot ha^{-1}$)*	*Average spread diameter of wetted soil (mm)*	*Average depth of injection (mm)*
2.5	*0.56*	*3298.80*	*2476.57*	*120.53*	*28.00*
	0.70	*2960.93*	*1775.13*	*107.30*	*27.70*
	0.83	*2781.80*	*1390.90*	*99.07*	*27.40*
3.0	*0.56*	*3673.60*	*2757.97*	*160.67*	*35.40*
	0.70	*3495.10*	*2095.40*	*151.20*	*35.20*
	0.83	*3316.93*	*1658.47*	*140.53*	*35.00*
3.5	*0.56*	*4539.33*	*3407.90*	*170.63*	*38.30*
	0.70	*4248.43*	*2547.03*	*160.53*	*38.20*
	0.83	*3939.33*	*1969.67*	*150.40*	*38.00*
$C.D_{(0.05)}$					
A		*34.258*	*21.655*	*0.730*	*0.726*
B		*34.258*	*21.655*	*0.730*	*N.S.*
A x B		*59.336*	*37.507*	*1.265*	*N.S.*

Effect of operating pressure and peripheral speed of metering system on depth of injection. The effect of operating pressure on depth of injection was significant at 5% level of significance however; the effect of peripheral speed was not significant at 5% level of significance. Depth of injection increased with the increase in operating pressure. The peripheral speed had not significant effect on depth of injection.

Effect of operating pressure on discharge variation within injectors. The mean discharge rate for different injectors within a spoke wheel varied from 382.0 to 453.5 ml·min^{-1} at operating pressure of 2.5 kg·cm^{-2}; 456.8 to 505.1 ml·min^{-1} at 3.0 kg·cm^{-2} and 542.1 to 623.4 ml. min^{-1} at 3.5 kg.cm^{-2} operating pressure (Tab. 3). The lowest discharge variation was found at operating pressure of 3.0 kg·cm^{-2} and peripheral speed of 0.70 m·s^{-1} with highest uniformity of fertilizer application of 98.5%. The highest discharge variation among different injectors within a rotary wheel was observed at operating pressure of 2.5 kg·cm^{-2} and peripheral speed of 0.83 m·s^{-1}. The coefficient of uniformity for all the operating pressure viz. 2.5, 3.0, and 3.5 kg·cm^{-2}, was over 97 % with a range of 97.8 % to 98.5 %. The highest coefficient of uniformity in discharge rate was observed at operating pressure of 3.0 kg·cm^{-2} and peripheral speed of 0.70 m·s^{-1}.

Table 3. Effect of peripheral speed and operating pressure on discharge variation among different injectors within a spoke wheel

Peripheral speed (min^{-1})	*Injector discharge (ml·min^{-1}) Injector No.*								*Mean discharge (ml·min^{-1})*	*S.D*	*C.V (%)*	*Uniformity of fertilizer application (%)*
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*				
A. Operating Pressure: 2.5 kg·cm^{-2}												
33.3	*450*	*460*	*454*	*447*	*442*	*455*	*460*	*460*	*453.5*	*9.6*	*2.11*	*97.9*
41.7	*406*	*410*	*408*	*400*	*410*	*415*	*400*	*408*	*407.1*	*6.7*	*1.65*	*98.4*
50.0	*395*	*380*	*386*	*390*	*375*	*380*	*375*	*375*	*382.0*	*8.4*	*2.19*	*97.8*
B. Operating Pressure: 3.0 kg·cm^{-2}												
33.3	*505*	*510*	*506*	*515*	*495*	*500*	*495*	*515*	*505.1*	*8.3*	*1.63*	*98.4*
41.7	*476*	*490*	*480*	*495*	*470*	*475*	*480*	*475*	*480.1*	*7.2*	*1.50*	*98.5*
50.0	*450*	*460*	*455*	*460*	*455*	*465*	*448*	*455*	*456.8*	*8.4*	*1.83*	*98.2*
C. Operating Pressure: 3.5 kg·cm^{-2}												
33.3	*620*	*615*	*615*	*625*	*630*	*625*	*635*	*630*	*623.4*	*12.9*	*2.08*	*97.9*
41.7	*580*	*590*	*595*	*585*	*585*	*575*	*590*	*575*	*584.4*	*10.2*	*1.74*	*98.3*
50.0	*540*	*550*	*545*	*540*	*548*	*540*	*535*	*540*	*542.1*	*11.5*	*2.12*	*97.9*

Effect of operating pressure and simultaneous injectors opening on discharge variation. The effect of operating pressures and number of simultaneous injectors opening on discharge variation is given in Tab. 4. There was some discharge variation with the number of injectors opening. With increase in number of simultaneous injectors opening, discharge variation increased. The highest discharge variation was recorded at operating pressure of 3.5 kg·cm^{-2} with coefficient of variation of 1.14, while the lowest discharge variation was found at operating pressure of 3.0 kg·cm^{-2} with coefficient of variation of 0.88. This discharge variation was considered small and reasonable.

Selection of the optimum peripheral speed and operating pressure. The average application rate of 1.969,67 l·ha^{-1} was obtained at peripheral speed of 0.84 m·s^{-1} and operating pressure of 3.5 kg·cm^{-2}; while the application rate of 2.095,40 l·ha^{-1} was obtained at peripheral speed of 0.70 m·s^{-1} and operating pressure of 3.0 kg·cm^{-2}, which were close to liquid urea application rate (2.000 l·ha^{-1}) used in the design of current metering mechanism. The spread diameter of wetted soil was significantly higher (151.20 mm) at peripheral speed of 0.70 m·s^{-1} and operating pressure of 3.0 kg·cm^{-2} than that of 150.40 mm at peripheral speed of 0.83 m·s^{-1} and operating pressure of 3.5 kg·cm^{-}

^{2}. It is also evident from the Tab. 4 that a peripheral speed of 0.70 m·s^{-1} and 3.0 kg·cm^{-2} operating pressure of metering system resulted into lowest coefficient of discharge variation (1.5%). Therefore, a peripheral speed of 0.70 m·s^{-1} (forward speed of 2.50 km·h^{-1}), operating pressure of 3.0 kg·cm^{-2} and application rate of 2.095 l·ha^{-1} were selected as optimum speed, operating pressure and liquid urea solution application rate for the field operation of self propelled walk behind nitrogen (liquid urea) applicator.

Table 4. Effect of operating pressure and number of injector opening on discharge variation among different rotary wheels

No. of injector opens at a time	Average discharge rate (ml·min^{-1})						
	Spoke wheel No.				Mean	S.D.	C.V (%)
	1st	2nd	3rd	4th			
Operating pressure: 2.5 kg·cm^{-2}							
1	3888.33	0.00	0.00	0.00	3888.33	46.65	1.22
2	3885.00	3825.00	0.00	0.00	3855.00		
3	3846.70	3811.70	3770.00	0.00	3809.47		
4	3833.33	3795.00	3763.00	3743.30	3783.66		
Operating pressure: 3.0 kg·cm^{-2}							
1	5190.00	0.00	0.00	0.00	5190.00	44.98	0.88
2	5165.00	5110.33	0.00	0.00	5137.67		
3	5105.33	5100.67	5097.69	0.00	5101.23		
4	5099.10	5091.18	5089.20	5081.32	5090.20		
Operating pressure: 3.5 kg·cm^{-2}							
1	6368.30	0.00	0.00	0.00	6368.30	71.73	1.14
2	6353.30	6305.00	0.00	0.00	6329.15		
3	6308.30	6295.00	6288.30	0.00	6297.20		
4	6234.21	6229.43	6209.32	6128.64	6200.40		

CONCLUSIONS

The operating pressure and peripheral speed of metering system had significant impact on the discharge rate of the metering mechanism which further affects the application rate of nitrogen (liquid urea) to be applied. The discharge rate of the metering mechanism decreased as the peripheral speed of mechanism increased from 0.56 to 0.83 m·s^{-1} and increased as the operating pressure of the pump increased from 2.5 to 3.5 kg·cm^{-2}. The lowest discharge variation within injectors was found at operating pressure of 3.0 kg·cm^{-2} and peripheral speed of 0.70 m·s^{-1} with highest uniformity of fertilizer application of 98.5%. There was some discharge variation with the number of simultaneously injectors opening. With the increase in number of simultaneously injector opening, discharge variation increases.

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RAZVOJ I STANDARDIZACIJA MERNOG MEHANIZMA NA UREĐAJU ZA APLIKACIJU AZOTA (TEČNE UREE) TAČKASTIM UBRIZGAVANJEM

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Sažetak: Postojeći metod primene uree na površini tretiranoj malčom slame sa direktno sejanom pšenicom je podložan gubicima azota. Azot (tečna urea) može biti apliciran kako bi se izbegao rizik od gubitka azota, ali merni mehanizam za azot (tečnu ureu) trenutno nije dostupan. Zato je razvijen i u laboratorijskim uslovima testiran uređaj za merenje azota. Radni pritisak i obimna brzina mernog mehanizma imali su značajan uticaj na normu aplikacije. Intenzitet pražnjenja je bio u direktnoj korelaciji sa radnim pritiskom i u obrnutoj korelaciji sa obimnom brzinom mernog sistema. Na osnovu ispitivanih veličina, za rad u poljskim uslovima određeni su sledeći parametri: obimna brzina od 0.70 $m \cdot s^{-1}$ (radna brzina od 2.5 $km \cdot h^{-1}$), radni pritisak od 3 $kg \cdot cm^{-2}$ i norma aplikacije rastvora azota (tečne uree) od 2.095 $l \cdot ha^{-1}$. Rezultati istraživanja u ovoj studiji

će unaprediti upotrebu uređaja tačkastu aplikaciju azota (tečne uree) na parcelama sa usevima na slamenom malču.

Ključne reči: *norma pražnjenja, merni mehanizam, aplikacija azota (tečna urea), obimna brzina, radni pritisak*

Prijavljen: *Submitted*:	08.04.2015.
Ispravljen: *Revised*:	13.08.2015.
Prihvaćen: *Accepted*:	12.10.2015.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XL
Broj 4, 2015.
Strane: 57 - 64

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 57 - 64

UDK: 621.3

Originalni naučni rad
Original scientific paper

OPTIMIZATION OF PROCESS PARAMETERS FOR THE PRODUCTION OF VEGETABLE CHUTNEY POWDER FOR ITS MAXIMUM NUTRIENT CONTENT

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Abstract: Vegetable chutney powder is a ready to cook product which is prepared using different ingredients. Vegetable chutney puree was dried using tray drier at different temperature and with different puree thickness. Response Surface Methodology is used to determine the effect of temperature and thickness on the quality characteristics of vegetable chutney powder. Totally 13 combinations of experimental trials were performed to understand the effect of processing parameters on different effects of vegetable chutney powder. Analysis of variance was performed for all the dependent variables such as temperature and thickness and the predicted R^2 value of protein and carbohydrate were 0.9821 and 0.9634 respectively. The final optimized temperature and thickness for the vegetable chutney powder was found to be 40°C and 3mm respectively. The color value (A-value) and moisture content of vegetable chutney powder was analyzed statistically using *SPSS* 20 and found both the values were significantly influenced by drying temperature.

Key words*: response surface methodology, optimization, central composite design, vegetable chutney powder*

INTRODUCTION

Urban lifestyle, increased prevalence of nuclear family, rising disposable income, improving shelf life of the processed food and reduced cooking time are the major reason for population opting for ready to cook products [1]. Chutneys, pickles and chutney powders are consumed along with rice, breakfast items as a side dish, which

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The authors are grateful to the management of SRM University for the facilities and encouragement.

also increase appetite are considered to be traditional food [2]. Earlier studies in this field includes instant curry leaf chutney powder [3], tamarind leaf chutney powder [4], raw mango chutney powder [5], raw tamarind chutney powder [2] and amla chutney powder [6] are the earlier studies.

Vegetable chutney powder prepared using mixed vegetable such as carrot, beans, capsicum, tomato along with spices was considered to be nutrient rich product as it has all nutrient such as vitamin A, vitamin C, vitamin K, biotin, Manganese derived from mixed vegetable. Extensive reviews conducted in this topic revealed that there was no earlier work in mixed vegetable chutney powder.

Drying process is defined as simultaneous process of heat and mass transfer between the product to the drying air that consists on excess moisture content removal from the product by means of evaporation process, generally caused by heated air convection forces with the objective to maintain the product quality during the storage [7]. Tray dryer is widely used in agricultural drying because of its simple design and capability to dry products at high volume. A tray dryer consists of several stacks of trays placed in an insulated chamber in which hot air is distributed by a fan or natural flow. The air temperature is usually controlled by a thermostat which is normally set between 50°C and 70°C [8].

Response Surface Methodology (*RSM*) is a collection of statistical and mathematical techniques useful for developing, improving and optimization of the process. Statistical software Stat-Ease was used for numerical and graphical optimization of experimental data [9]. The main advantage of *RSM* is to evaluate multiple parameters and their interactions [10]. Optimization theory consist of a body of numerical methods for finding and identifying the best candidate from a collection of alternatives without having to explicitly evaluate all possible alternatives [11]. Once an appropriate approximating model is obtained, this model can then be analyzed using various optimization technique to determine the optimum conditions for the process [12].

The present study was formulated with an objective of optimizing the drying process parameters for making vegetable chutney powder with acceptable sensory and nutritional quality using *RSM* approach.

MATERIALS AND METHODS

Collection of raw materials. The particular variety of vegetables needed for preparing vegetable chutney powder were purchased fresh from the local market on the day of processing in order to ensure that there is no nutrient loss due to storage of vegetables. The other ingredients such as garlic, ginger, sesame seeds, oil, cumin seeds, mustard, red chilies, salt and tamarind were also purchased from the local market in bulk qualities and used throughout the study to reduce the error due to varietal influence.

Preparation of vegetable chutney powder. Various vegetables and other ingredient used for the preparation of chutney powder such as carrot, brinjal, green beans, capsicum, tomato, onion, ginger, garlic, oil, cumin seeds, red chilies, sesame seeds, salt and tamarind were added with sufficient amount of water to get mixed vegetable puree. Chutney puree was prepared by two different methods namely frying method and boiling method. In frying method all ingredients were fried in oil using medium flame whereas in boiling method, pressure cooking of all ingredients without oil in medium flame for

10 minutes. Sensory analysis was used to select the method which yielded good quality mixed vegetable puree. Using the selected method, puree was then dried in a tray drier for a definite temperature (40°C, 50°C, 60°C) and thickness (1mm, 2mm, 3mm). The experimental designs for these drying parameters were obtained using Central Composite Rotatable Design (*CCRD*) obtained from *RSM* (Tab. 1). All the samples were dried till a concordant weight was reached to calculate the drying time.

Quality evaluation of vegetable chutney powder. Prepared vegetable chutney powder was analyzed for its moisture content, color value (A-value), protein and carbohydrate using standard method. Moisture content was analyzed using hot air oven method [13]. The color value (A-value) of the chutney powder was measured using the Hunter LAB Colorimeter [14]. While the Carbohydrate was determined by Anthrone reagent method [15] and the protein content was estimated using Kjeldahl method [16]. The effect of processing temperature and thickness on the nutritional content, moisture and color value (A-value) of prepared chutney was studied. The moisture content and color value (A-value) of the experimental trials were analyzed by *ANOVA* using Statistical Package for Social Scientists (*SPSS*) software, version 20.0 to evaluate the difference at $p<0.05$. The data were analyzed to get mean value with standard deviation (Tab. 4).

Model development and experimental data analysis. Totally 13 trials were performed and the responses such as protein and carbohydrate were obtained (Tab.1). The response value were fit into the quadratic model and ANOVA was performed to understand the effect of process parameter on the responses. The retrieved model were fitted with different process order like linear, interactive and quadratic to get sequential model sum of squares and model summary for validating the model and confirming the goodness of fit of the model.

Table 1. Effect of process parameters on protein, carbohydrate, moisture content and A-value of prepared vegetable chutney powder

Run	*Temperature (°C)*	*Thickness (mm)*	*Protein (mg)*	*Carbohydrate (mg)*	*Moisture content (%)*	*Colour value (A-value)*
1	50.00	1.00	0.53	2.9	4.4	12.31
2	40.00	3.00	0.88	5.5	6.4	9.12
3	50.00	2.00	0.65	3.5	4.7	12.96
4	40.00	1.00	0.66	4.7	5.8	9.07
5	60.00	3.00	0.65	3.7	4.4	14.09
6	50.00	2.00	0.65	3.2	4.6	12.96
7	50.00	2.00	0.61	3.2	4.5	13.18
8	50.00	3.00	0.77	4.4	4.7	12.97
9	50.00	2.00	0.61	3.5	4.6	12.96
10	60.00	2.00	0.56	2.7	4.4	13.72
11	60.00	1.00	0.52	2.2	4.2	13.03
12	50.00	2.00	0.65	3.5	4.6	13.18
13	40.00	2.00	0.80	5.0	6.2	9.32

Model validation. The developed model was evaluated by its R^2 value and Lack of Fit test. Set of experimental trials were performed based on the optimized process conditions and used for the model validation. The experimental and predicted values of process temperature and thickness were also used for the validation of the model. The R^2 values were computed to check the suitability of analysis and closure the R^2 value to unity indicates the goodness of fit of the model.

Optimization. Numerical and graphical optimization was carried out to get the optimum process conditions to retain maximum protein and carbohydrate content in the chutney powder.

RESULTS AND DISCUSSION

Regression analysis for the responses with selected model. Generally the model that fits into the design may produce misleading results which indicates that the validation of the analyzed model is necessary. From Tab. 2 it is clear that the quadratic model gives the maximum R^2 and lesser *p*-value. Further the “Adjusted R^2” and “Predicted R^2” of the quadratic model were found to be maximum ensuring the validation of model (Eq.1). Tab. 2 displays the ANOVA and the regression coefficient of all the model with their coefficients of determination. The statistical tool implies that the proposed model is good for the responses like protein and carbohydrate value possessing no significant lack of fit. The R^2 value of protein and carbohydrate was 0.9821, 0.9634 respectively which indicates satisfactory R^2 value for all the responses since the values are closer to unity [17]. The lesser the value of R^2 denotes the existence of less relevant dependent variables.

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 + b_{11}X_{12} + b_{22}X_{22} + b_{33}X_{32} \quad (1)$$

Table 2. Model adequacy

Source	*Std.dev*	R^2	*Adjusted* R^2	*Predicted* R^2	*Remarks*
Model Summary Statistics					
Protein Value					
Linear	*0.031*	*0.9275*	*0.9130*	*0.8757*	*Suggested*
2FI	*0.029*	*0.9429*	*0.9238*	*0.8645*	*Suggested*
Quadratic	*0.018*	*0.9821*	*0.9693*	*0.9533*	*Suggested*
Carbohydrate value					
Linear	*0.037*	*0.8760*	*0.8512*	*0.7826*	*Suggested*
2FI	*0.037*	*0.8872*	*0.8496*	*0.6486*	*Suggested*
Quadratic	*0.024*	*0.9634*	*0.9372*	*0.7943*	*Suggested*

Effect of process parameter on protein content. The model obtained for predicting the protein value are highly significant at 0.1% level which is presented in Tab. 3. The effect of process parameter on the protein content of the vegetable chutney powder is given in Fig.1A. The protein value significantly decreased during the increase in temperature because the higher the process temperature the more is the denaturation of protein molecules present in the sample [18]. Interactive effect between temperature and thickness exhibited negative impact on the protein content of vegetable chutney powder.

By neglecting the non significant terms in Eq.1 with the coded values of independent variables, Eq.2 describes the effect of processing on the protein value.

$$Protein = +0.63-0.089X_1+0.086X_2-0.022\,X_1\,X_2+0.026\,X_1^2\ (R^2=0.9821) \qquad (2)$$

Effect of process parameter on carbohydrate content. From the model variance analysis, the quadratic model is best suited for predicting the carbohydrate content (p<0.05) [19]. From the ANOVA it is clear that the drying temperature and the thickness of vegetable puree significantly affects the carbohydrate content of the prepared product. As the temperature of the process increases the carbohydrate content of the vegetable chutney decreases markedly and also there is gradual increase in the carbohydrate content with the increase in puree thickness during the drying process (Fig.1B). By neglecting the non significant terms in Eq.1 and with the coded values of independent variables, the following Equation (Eq.3) describes the effect of significant process variables on carbohydrate content of vegetable chutney powder.

$$Carbohydrate = +0.34-0.094\,X_1+0.055\,X_2+0.030\,X_1^2\ (R^2=0.9634) \qquad (3)$$

Table 3. ANOVA of the quadratic model for the variables

Variable	*Protein value*		*Carbohydrate value*	
	Coefficient of estimate	*p value*	*Coefficient of estimate*	*p value*
Model		*<0.0001*[a]		*<0.0001*[a]
X_1	*-0.089*	*<0.0001*[a]	*-0.94*	*<0.0001*[a]
X_2	*0.086*	*<0.0001*[a]	*+0.55*	*<0.0001*[a]
$X_1 X_2$	*-0.022*	*0.0442*[c]	*+0.18*	*0.1867*
X_1^2	*+0.026*	*0.0072*[b]	*+0.30*	*0.0123*[c]
X_2^2	*+0.011*	*0.1543*	*+0.20*	*0.0595*
Lack of fit		*0.8197*[d]		*0.1235*[d]
Suggested	*quadratic*	*quadratic*	*quadratic*	*Quadratic*
Model	*significant*	*significant*	*significant*	*Significant*
R^2	*0.9821*		*0.9634*	

[a] - Significant at 0.001 level; [b] - Significant at 0.01 level;
[c] - Significant at 0.05 level; [d] - Not significant.

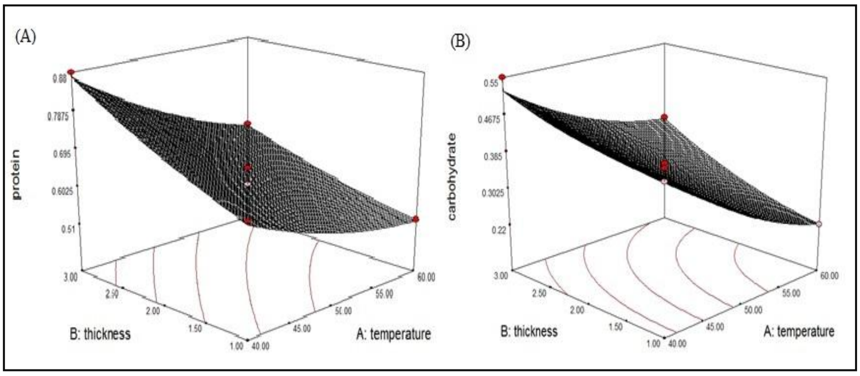

Figure 1. (A) 3D response model of protein with respect to temperature and thickness, (B) 3D response model of carbohydrate with respect to temperature and thickness

Effect of process parameter on moisture content and color value (A-value). Moisture content and color value (A-value) was analyzed for all 13 combinations of trials. From the *ANOVA*, p value for moisture content and colour value (A-value) is less than 0.05 with respect to temperature (p<0.05) which indicates that temperature has significant influence on the moisture content and colour attributes of vegetable chutney powder while the p-value with respect to thickness has no significant effect on the moisture content and colour value (A-value) as given in Tab. 4.

Table 4. ANOVA for effect of process parameters on moisture content and colour value

Independent variables	*Moisture content*		*Colour value (A-value)*	
	Mean	*Probability*	*Mean*	*Probability*
Temperature	*5.01±0.867*	*0.000*[a]	*11.87±2.083*	*0.000*[a]
Thickness		*0.896*[b]		*0.940*[b]

[a]- significant; [b]- Not significant.

CONCLUSION

From the current study it is clear that the drying process parameters; drying temperature and thickness of vegetable puree has significant influence on the nutrient content of vegetable chutney powder. Experimental data were fit into the quadratic Equation to get the prediction Equation which will be suitable for predicting the nutrient content of the chutney powder. Numerical and graphical optimization was performed to optimize the drying process parameters. The optimum temperature of drying and thickness of vegetable chutney puree was found to be 40°C and 3mm respectively. Maximum desirability function method was used to carry out numerical optimization and was found to be 0.969. At optimized conditions the predicted values for protein and carbohydrate were found to be 0.8686 and 5.209 mg/100g of chutney powder, respectively. Experiments were conducted using the predicted values to ascertain the suitability of the model for predicting the responses. This study will be useful for developing various ready to cook instant foods, balancing the nutrient loss during the processing.

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OPTIMIZACIJA PARAMETARA PROIZVODNJE MLEVENOG POVRĆA ZA POSTIZANJE MAKSIMALNOG HRANLJIVOG SADRŽAJA

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Sažetak: Mleveno povrće je proizvod spreman za kuvanje koji je pripremljen od različitih sastojaka. Čatni pire od povrća je sušen na različitim temperaturama i različitom debljinom sloja. Metodologija površinskog odgovora je upotrebljena za određivanje uticaja temperature i debljine na kvalitet samlevene slese. Ukupno 13 kombinacija eksperimantalnih proba su urađene da bi se shvatio uticaj parametara procesa. Analizom varijanse svih zavisno promenljivih, kao što su temperature i debljina i predviđena R^2 vrednost proteina i ugljhenih hidrata bili su 0.9821 i 0.9634, redom. Dobijene su finalne optimalne vrednosti temperature i debljine od 40°C i 3 mm, redom. Vrednost boje (A-vrednost) i sadržaj vlage mlevenog povrća bio je statistički analiziran upotrebom *SPSS* 20 i zaključeno je das u obe vrednosti bile pod značajnim uticajem temperature sušenja.

Ključne reči*: metodologija površinskog odgovora, optimizacija, centralni kompozit, mleveno povrće*

Prijavljen: *Submitted*:	19.04.2015.
Ispravljen: *Revised*:	
Prihvaćen: *Accepted*:	17.09.2015.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XL
Broj 4, 2015.
Strane: 65 - 74

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 65 - 74

UDK: 633.85

Originalni naučni rad
Original scientific paper

EFFECT OF TEMPERATURE AND PRESSURE ON MOISTURE DIFFUSION CHARACTERISTICS OF PADDY (Cv. MTU 1075)

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Abstract*:* Parboiling is an important and energy intensive unit operation in rice processing. Proper management of parboiling can reduce the energy requirement during parboiling and the associated cost. Soaking and steaming are the two major steps in parboiling. Soaking of paddy is usually carried out under atmospheric pressure, which takes more time. The temperature of soak water affects the rate of moisture adsorption and diffusion. The pressure during soaking and steaming also affects the process and consequently, affects the overall economics of parboiling. The hydration characteristic of paddy (Cv. MTU 1075) was studied at different conditions with the basic objective to standardize parameters for these unit operations. Soaking was carried out at four levels of soaking temperature under atmospheric pressure. Similarly hydrostatic soaking at pressure levels of 2.0, 4.0 and 6.0 $kg \cdot cm^{-2}$ was studied at a constant soak water temperature of 70°C. Steaming was carried out at 0.5, 1.0, 1.5, 2.0 and 2.5 $kg \cdot cm^{-2}$ pressure levels. The initial moisture content of paddy was varied at three levels. It was observed that the soaking temperature and pressure and steaming pressure affected the rate of moisture absorption by the grain and thus the time requirement. The diffusion coefficient was independent of initial moisture content and showed Arrhenius type relationship with temperature of soaking and steaming. The diffusion coefficient of paddy ranged between 8.939 x 10^{-5} to 2.678 x 10^{-4} $cm^2 \cdot min^{-1}$ for steaming under pressure, 7.01 x 10^{-6} to 1.399 x 10^{-5} $cm^2 \cdot min^{-1}$ for hydrostatic pressure soaking at 70°C and 1.898 x 10^{-6} to 1.11 x 10^{-5} $cm^2 \cdot min^{-1}$ for soaking under atmospheric pressure at different temperature. The diffusion constant was calculated as 0.01345 $m^2 \cdot min^{-1}$ and activation energy for moisture diffusion was 35.19 $kJ \cdot g\text{-}mol^{-1}$.

Key words: *parboiling, hydrostatic soaking, steaming, diffusion coefficient*

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INTRODUCTION

Rice is the staple food of India and more than 50% of the rice produced is consumed in the country in parboiled form. Rice is parboiled in many countries of South East Asia and in some developing countries in South Africa. Parboiling increases milling yield, storage stability and nutritional value of rice and changes the taste of cooked rice which is liked by many classes of people [1]. Conventional parboiling method involves three steps, viz. soaking, steaming and drying. All these unit operations consume huge amount of energy. Hence, the development of new energy efficient processes and improvement in the existing processing operation for parboiling has been major field of research. Some studies have been conducted in the past to modify the conventional paddy parboiling methods in view of energy conservation and initial investment [2, 3]. Some attempts were also made even to eliminate the steaming process in parboiling, which could help in avoiding the high investment due to the installation of a boiler [2, 4-7]. However, to affect proper gelatinization, proper absorption and distribution of moisture in the grain along with infusion of heat energy are quite important. Some studies have been conducted on the hydration characteristics of paddy to present the moisture absorption behaviour of rice during soaking and steaming, which ultimately facilitates the design of the parboiling process [8-10]. However, the process and parameters may vary for different varieties of paddy. Even for a single variety of paddy the physical and other engineering properties change with the moisture content [11]. Therefore, there is a need to study the rate of moisture absorption and diffusion by the grain at different process conditions to standardize different parameters for processing, and hence, the moisture absorption characteristics of a popular and widely cultivated variety of paddy (Cv. MTU 1075, local name: *Pushyami* also known as *IET 18482*) was studied under different soaking temperature and pressure, and steaming pressure at different initial moisture levels.

MATERIALS AND METHODS

Freshly harvested paddy was shade dried and the moisture content was determined just before the start of the experiment. Three initial moisture contents in the range of 13-30 g per 100 g dry matter were taken for the study. The temperature of soak water was maintained at 40°, 50°, 60° and 70°C. The soaking experiment was carried out in a hot water bath maintained at ±2°C. The moisture content of paddy was measured at different time in hot air oven to determine the rate of moisture absorption. The moisture gain during hydrostatic soaking of paddy was studied at 2.0, 4.0 and 6.0 kg·cm^{-2} absolute pressure in a hydrostatic pressure vessel. During soaking of paddy under pressure, the temperature of soak water was kept constant at 70°C. The soaking experiment was continued for up to 6 hours.

The moisture absorption during steaming was studied by employing five levels of steam pressure, viz. 0.5, 1.0, 1.5, 2.0 and 2.5 kg·cm^{-2}. The pressure vessel was suitably modified for the purpose. The observations were taken up to 25 minutes.

The rate of moisture absorption during the above experiment was analyzed to find out the values of diffusion coefficient, diffusion constant and the activation energy for moisture diffusion.

Diffusion coefficient. The moisture movement in paddy grain during soaking and steaming is governed by the basic principle of moisture diffusion. Analytical expressions predicting moisture movement in a grain based on diffusion theory have been used by [3] with suitable assumptions. Application of these equations requires knowledge of two parameters, diffusion coefficient and saturation moisture content for different hydrating conditions.

It was assumed that the surface layers of the grain attained equilibrium with the medium and reached the saturation moisture content immediately after exposure to the hydrating medium. Diffusion of moisture from the surface layers into the grain took place due to moisture concentration gradient between the adjacent layers in the kernel, as governed by Fick's law.

The form of equation obtained was [3]:

$$\frac{\partial C}{\partial t} = -\phi\left(\frac{\partial q}{\partial r} + \frac{2}{r}q\right) \tag{1}$$

where:

ϕ	[-]	- shape factor of paddy,
C	[$g \cdot cc^{-1}$]	- moisture concentration at any characteristic radius 'r' and time,
t	[sec]	- time,
q	[$g \cdot cm^{-2} \cdot min^{-1}$]	- rate of mass transfer per unit area of cross section,
r	[cm]	- characteristic radius within the paddy grain.

For grain, ϕ is given by:

$$\phi = \frac{s}{v} x \frac{a}{3} \tag{2}$$

where:

s	[cm^2]	- surface area of paddy grain,
υ	[cm^3]	- volume, for the paddy grain,
a	[cm]	- characteristic dimension of paddy grain (half of the breadth of paddy grain)

As per Fick's law:

$$q = -D\frac{\partial C}{\partial r} \tag{3}$$

where:

D [$cm^2 \cdot min^{-1}$] - diffusion coefficient.

Substituting the values:

$$\phi D\left(\frac{\partial^2 C}{\partial r^2} + \frac{2}{r}\frac{\partial C}{\partial r}\right) = \frac{\partial C}{\partial t} \tag{4}$$

The equation is similar to diffusion equation for a sphere under similar conditions and is the basic equation governing the moisture movement in a paddy grain at any characteristic radius *r* and time of increment *t*.

Eq. (4) was solved initially for constant values of diffusion coefficient and saturation moisture content and then the solution was modified for varying values of diffusion coefficient and saturation moisture content and then the solution of the above equation with suitable initial and boundary conditions, and further simplification yielded the following equations [8]:

$$\frac{M_t - M_0}{M_s - M_0} = \Psi(t) \tag{5}$$

where $\Psi_{(t)}$ is the infinite series defined as:

$$\psi(t) = 1 - \frac{6}{\pi^2}\sum_{n=1}^{\infty}\frac{1}{n^2}\exp(-n^2\pi^2\phi Dt/a^2) \quad (6)$$

where:

$\Psi_{(t)}$ [-] - infinite series to find out moisture ratio,
M_0 [-] - moisture content at the beginning (at time $t = 0$),
M_t [-] - moisture content at any time, t,
M_s [-] - saturation moisture content.

The use of Eq. (5) for determination of D from the moisture ratio at any time requires summation of infinite series to the point of convergence. An empirical relationship was developed to estimate the value of the series as follows.

$$\psi(t) = -0.028\,d + 1.029\,d^{\,0.54} - 0.0221 \quad (7)$$

In this equation d is a dimensionless variable, which is defined as:

$$d = \frac{\pi^2\phi Dt}{a^2} \quad (8)$$

where:

d [-] - dimensionless variable,
D [$cm^2 \cdot min^{-1}$] - diffusion coefficient,
a [cm] - half the breadth of paddy grain (characteristic outer radius of paddy grain).

Thus, from the moisture ratios the value of diffusion coefficient was obtained.

Saturation moisture content. The principle used in the method is that for constant values of saturation moisture content M_S and diffusion coefficient D, the moisture gain $(Mt - Mo)$ by a grain at any time is directly proportional to the moisture driving potential $(Ms - Mo)$.

$$(M_t - M_0) \propto (M_S - M_0) \quad (9)$$

or

$$(M_t - M_0) = k \cdot (M_S - M_0) \quad (10)$$

$$(M_t - M_0) = -k \cdot Mo + \delta, \text{ where } \delta = k \cdot Ms \quad (11)$$

The diffusion coefficient was correlated to treatment temperature by Arrhenius type of relationship.

$$D = D_0 e^{E_a/RT} \quad (12)$$

where:

E_a [cal/g-mole] - activation energy,
R [-] - gas constant,
T [K] - temperature of treatment.

RESULTS AND DISCUSSION

The MTU 1075 is a slender variety of paddy. The average length, breadth and thickness of the samples were found out to be 5.74±0.084 cm, 2.1±0.224 cm and 1.84±0.089 cm. The length breadth ratio was observed to be 3.132±0.161.

Hydration characteristics of paddy during hot water soaking. Fig. 1 shows the moisture gain of paddy for different durations of soaking at different temperatures and initial moisture contents. It was observed that the rate of moisture gain reduced with time as expected. At any given temperature and duration of soaking, the rate of moisture gain was higher with lower initial moisture content than that with higher moisture content. This was due to the fact that rate of moisture diffusion into the grain was directly proportional to the difference between saturation moisture content and initial moisture content, i.e. the moisture driving potential. Higher the soaking temperature higher was the rate of moisture absorption by the grain. The rate of moisture diffusion was higher initially up to about 60 min after which it decreased. At low initial moisture content variation in temperature from 40°C to 50°C caused increase in the moisture diffusion. However, no such difference was observed for higher moisture contents.

Hydration characteristics of paddy during pressure soaking. Fig. 2 shows the rate of moisture gain with respect to time for the paddy for three different pressures. The rate of moisture absorption decreased with time and the plots indicate logarithmic moisture migration. It was also observed that the rate of moisture migration was higher with lower initial moisture contents than that with higher initial moisture contents. Higher pressures resulted in higher moisture gain by the grain, but this increase in the rate of moisture migration was not noteworthy at higher pressures.

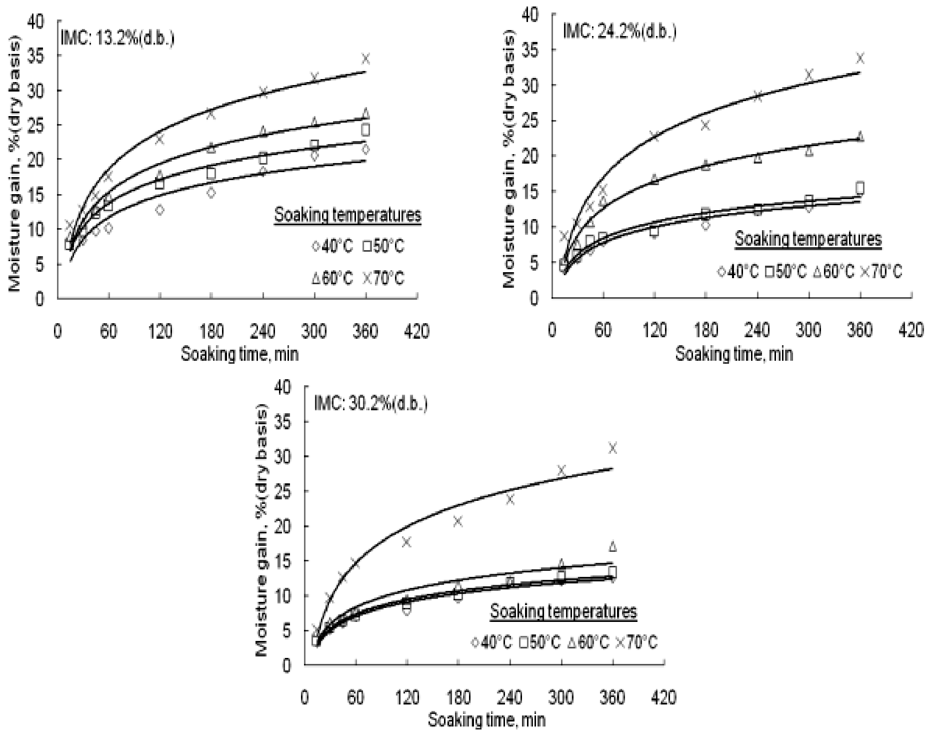

Figure 1. Moisture gain of paddy (MTU 1075) at different initial moisture contents and soaking temperatures

Hydration characteristics of paddy during steaming. The hydration curves for paddy for five levels of applied pressures, viz. 0.5, 1.0, 1.5, 2.0, 2.5 kg·cm^{-2} are shown in Fig. 3. The initial moisture contents were found out to be 13.5, 24.6 and 32.1 g per 100 g dry matter. The moisture diffusion in to the grain during steaming at these moisture levels took place at a much faster rate as compared to hot water soaking treatments. The moisture absorption rate of paddy was slower during the initial periods and it increased with increase in steaming time. Rate of moisture migration also depended upon the steam pressures and increased with the increase in steam pressure.

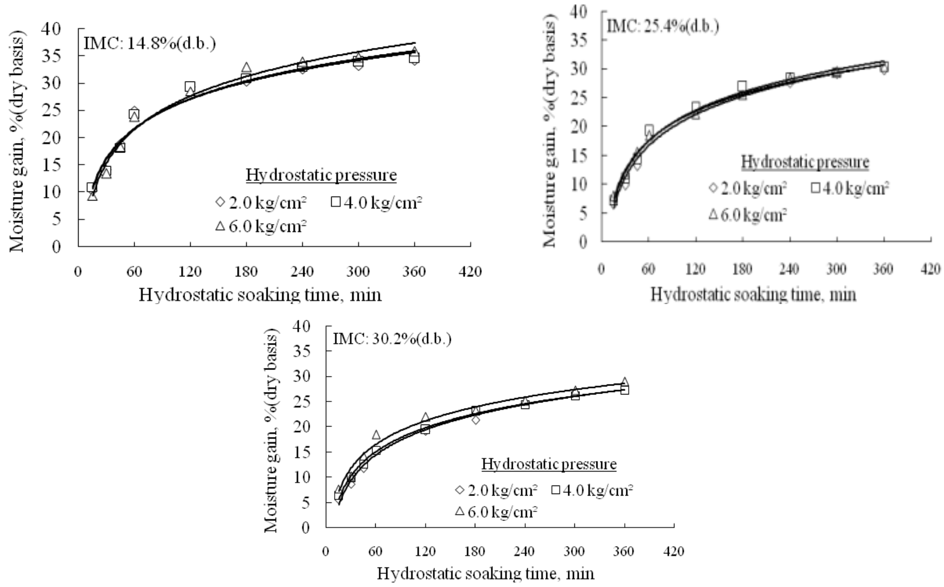

Figure 2. Moisture gain of paddy (MTU 1075) during soaking at different pressures

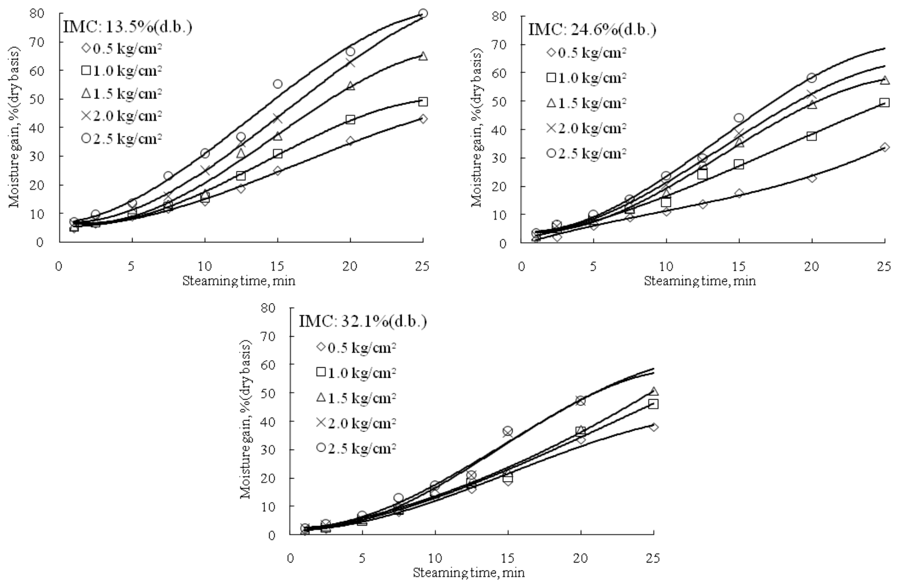

Figure 3. Moisture gain of paddy (MTU 1075) for different steaming pressures

In general, it was observed that the soaking temperature and pressure, and the steaming pressure greatly influenced the moisture absorption by the grain and in turn the time requirement for the process. Higher the pressure and temperature, less was the time requirement. However, the temperature and pressure of treatments should be decided on the basis of the final quality of parboiled grain.

Determination of diffusion coefficient. The saturation moisture contents for 40, 50, 60 and 70°C soaking temperatures remained almost constant for different durations of soaking. The maximum, minimum and mean values of the saturation moisture contents M_s along with the standard deviation values have been tabulated in Tab. 1. The mean values of M_s for all the temperatures were taken for the analysis.

Table 1. Saturation moisture contents for paddy (MTU 1075) as obtained by regression analysis for different soaking temperatures

Soaking temperature	Saturation moisture content, g per 100 g dry matter
40°C	54.2±4.8
50°C	52.3±4.9
60°C	52.4±6.8
70°C	53.5±4.2

Table 2. Diffusion coefficient of paddy (MTU 1075) during soaking under atmospheric pressure with three different initial moisture contents

Temperature [°C]	M_o=13.2 g per 100 g dry matter	M_o=24.2 g per 100 g dry matter	M_o=30.2 g per 100 g dry matter
40	1.898×10^{-06}	1.917×10^{-06}	2.431×10^{-06}
50	2.873×10^{-06}	2.150×10^{-06}	2.649×10^{-06}
60	3.702×10^{-06}	3.917×10^{-06}	3.771×10^{-06}
70	6.817×10^{-06}	1.111×10^{-05}	5.767×10^{-06}

Table 3. Diffusion coefficient of paddy (MTU 1075) at hydrostatic pressure soaking with three different initial moisture contents at 70°C

Hydrostatic pressure [$kg \cdot cm^{-2}$]	M_o=14.8 g per 100 g dry matter	M_o=25.4 g per 100 g dry matter	Mo=30.2 g per 100 g dry matter
2.0	7.158×10^{-06}	9.133×10^{-06}	1.047×10^{-05}
4.0	7.010×10^{-06}	9.770×10^{-06}	1.035×10^{-05}
6.0	7.227×10^{-06}	9.944×10^{-06}	1.399×10^{-05}

Table 4. Diffusion coefficient of paddy (MTU 1075) at different steaming pressures with three different initial moisture contents

Steaming pressure [$kg \cdot cm^{-2}$]	M_o=13.5 g per 100 g dry matter	M_o=24.6 g per 100 g dry matter	M_o=32.1 g per 100 g dry matter
0.5	1.119×10^{-04}	8.939×10^{-05}	2.342×10^{-04}
1.0	1.228×10^{-04}	1.971×10^{-04}	2.314×10^{-04}
1.5	2.340×10^{-04}	9.158×10^{-05}	2.744×10^{-04}
2.0	2.137×10^{-04}	1.437×10^{-04}	1.875×10^{-04}
2.5	2.678×10^{-04}	2.327×10^{-04}	2.328×10^{-04}

It was observed that the diffusion coefficient D did not exhibit any definite relationship with the initial moisture content and the moisture concentration in the grain at any time. However, the diffusion rate increased with increase in soaking or steaming temperatures. The mean values of the diffusion coefficients were taken for further calculations, which have been given in Tables 2-4. The amount of moisture migration was predicted using the average diffusion coefficient for a particular treatment.

As observed from these tables, the diffusion coefficient values during soaking varied between $1.898x10^{-6}$ to $1.11x10^{-5}$ whereas the diffusion coefficient of paddy during soaking was found to be $4.91x10^{-11}$ $m^2 \cdot s^{-1}$ by earlier researchers [9]. The diffusion coefficient was correlated to treatment temperature by Arrhenius type of relationship. The calculated values of diffusion coefficient *D* showed linear relationship with *1/T*, where *T* is the absolute temperature. The relationship obtained was:

$$D = 1.345\, e^{(-8407/RT)};\ R^2 = 0.9947 \qquad (13)$$

The values of diffusion coefficients obtained as above for the soaking and steaming treatments have been given in Tab. 5. The diffusion constant and the activation energy were calculated to be 0.01345 $m^2 \cdot min^{-1}$ and 35.19 $kJ \cdot mole^{-1}$, respectively, whereas the activation energy of paddy soaking was observed by earlier researchers to be 31.50 $kJ \cdot mole^{-1}$ for paddy [9]. The activation energy for IR 20 paddy was also found to vary in the range of 19.49-23.09 $kJ \cdot mole^{-1}$ [10]. However, the diffusion constants were observed to be in the range of 0.406-0.647 $m^2 \cdot s^{-1}$, which was much higher as compared to the observed values.

Table 5. Average values of diffusion coefficients of paddy (Cv. MTU 1075) at different treatment conditions

Treatment temperature [K]	*Pressure [kg·cm⁻²]*	*Diffusion coefficient (D)*
Soaking treatments		
313	*0.0*	*1.898 x 10^{-6}*
323	*0.0*	*2.557 x 10^{-6}*
333	*0.0*	*3.702 x 10^{-6}*
343	*0.0*	*6.817 x 10^{-6}*
Steaming treatments		
382	*0.5*	*2.196 x 10^{-5}*
391	*1.0*	*2.557 x 10^{-5}*
397	*1.5*	*2.988 x 10^{-5}*
404	*2.0*	*3.496 x 10^{-5}*
409	*2.5*	*4.835 x 10^{-5}*

It was observed that the steam pressure directly influenced the moisture absorption by the grain. Higher the pressure and temperature, lower was the time required to reach the saturation moisture content. However, the temperature and pressure of treatments should be decided on the basis of uniformity of gelatinisation and presence of white bellies in the kernels after the process.

Prediction of moisture gain at any time. Taking the average values of diffusion coefficient D at a particular soaking temperature or steaming pressure, the dimensionless parameter d was calculated using Equation 8. A regression equation was developed as below to predict the moisture ratio or $\psi(t)$.

$$MR = d_{\text{pred}} 0.52\, x\, 0.782;\ R^2 = 0.98 \qquad (14)$$

The predicted moisture content was then calculated using general equation

$$(Mt - Mo)_{\text{pred}} = MR_{\text{pred}}\, x\, (Ms - Mo) \qquad (15)$$

CONCLUSIONS

The moisture diffusion characteristics of paddy (Cv. MTU 1075) were studied during soaking at different temperatures under atmospheric pressure, soaking at elevated pressures at constant temperature of 70°C and steaming at different pressures to analyse the effects of these parameters on the moisture absorption rate, diffusion coefficients and to develop the relationship between the temperature and rate of diffusion. During soaking under pressure, the moisture absorption by the grain was logarithmic in nature. Higher pressure and temperature reduced the time requirement to reach the saturation moisture content for all conditions. However, the temperature and pressure of treatments should be decided on the basis of uniformity of gelatinisation and presence of white bellies in the kernels after the process. The diffusion coefficients were found out for all the experiments, which were observed to follow Arrhenius type relationship. The diffusion constant and activation energy were found out to be 0.01345 $m^2 \cdot min^{-1}$ and 35.19 $kJ \cdot g\text{-}mole^{-1}$, respectively.

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UTICAJ TEMPERATURE I PRITISKA NA DIFUZIJU VLAGE U PIRINČU (Cv. MTU 1075)

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Sažetak: Predkuvanje je važan i energetski intenzivan postupak u preradi pirinča. Pravilan postupak može da smanji potrošnju energije i prateće troškove. Natapanje i parenje su dva glavna koraka u ovom postupku. Natapanje pirinča se obično izvodi pod atmosverskim pritiskom, što traži više vremena. Temperatura vode utiče na adsorpciju i difuziju vlage. Pritisak pri natapanju i parenju takođe utiče na process, a time i na ukupne ekonomske efekte. Karakteristike hidriranja pirinča (Cv. MTU 1075) su ispitivane pod različitim uslovima sa osnovnim ciljem da se standardizuju parametri za ove operacije. Natapanje ke izvođeno pri četiri temperature pod atmosverskim pritiskom. Hidrostatičko natapanje je izvođeno pri pritiscima od 2.0, 4.0 i 6.0 $kg \cdot cm^{-2}$ na konstantnoj temperature od 70°C. Natapanje je izvođeno pod pritiscima od 0.5, 1.0, 1.5, 2.0 i 2.5 $kg \cdot cm^{-2}$. Inicijalni sadržaj vlage pirinča varirao je na tri nivoa. Uočeno je da temperatura i pritisak natapanja i pritisak parenja utiču na adsorpciju vlage u zrno, a time i na vreme trajanja postupka. Koeficijent difuzije je bio nezavistan od inicijalne vlažnosti i pokazao je Arrhenius odnos sa temperaturom natapanja i parenja. Koeficijent difuzije pirinča varirao je u interval 8.939 x 10^{-5} do 2.678 x 10^{-4} $cm^2 \cdot min^{-1}$ za parenje pod pritiskom, 7.01 x 10^{-6} do 1.399 x 10^{-5} $cm^2 \cdot min^{-1}$ za hidrostatičko natapanje na 70°C i 1.898 x 10^{-6} do 1.11 x 10^{-5} $cm^2 \cdot min^{-1}$ za natapanje pod atmosverskim pritiskom pri različitoj temperature. Izračunata vrednost difuzione konstante je bila 0.01345 $m^2 \cdot min^{-1}$, a aktivaciona energija za difuziju vlage 35.19 $kJ \cdot g\text{-}mol^{-1}$.

Ključne reči: *predkuvanje, hidrostatičko natapanje, parenje, koeficient difuzije*

Prijavljen: *Submitted*:	25.04.2015.
Ispravljen: *Revised*:	08.10.2015.
Prihvaćen: *Accepted*:	17.11.2015.

Univerzitet u Beogradu
Poljoprivredni fakultet
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Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XL
Broj 4, 2015.
Strane: 75 - 80

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 75 - 80

UDK: 631.67

Originalni naučni rad
Original scientific paper

COST ASSESSMENT OF THE COMBINED RAINWATER HARVESTING WITH SOLAR IRRIGATION

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Abstract: Water availability is becoming acute in all over the world. Increased water demands have generated interest in different systems. Rainwater harvesting is one of the promising way to meet water demand for agricultural irrigation. However, water transmission between water resources and the field requires energy. There are several ways for powering irrigation systems. One of the options is to use solar panels as an alternate energy source, and it is mainly use in where there is no electricity. This study represents the analysis of combined rainwater harvesting with monocrystalline or polycrystalline or amorphous silicon solar power based irrigation systems. The study found for all solar powered irrigation cost huge because of primary investment. Nevertheless, the need for fossil fuel can be decreased by using solar panels and proposed solution for the present energy crisis for the farmers.

Key words*: rainwater harvesting, solar panels, economic costs*

INTRODUCTION

Water resources are under threat due to a number of consecutive droughts, increasing ground water salinity and falling of ground water table by over exploitation [1]. Thus, different methods are analyses to water supply for agricultural irrigation. Rainwater harvesting is one of the way to meet irrigation water demand and becoming popular in different quantities.

The most basic need of all the people in the world is energy and it is needed more than ever [2]. Solar energy is the most abundant source of energy in the world. Solar power is not only an answer to today's energy crisis but also an environmental friendly form of energy. It is used widely for receiving electrical power with panels [3]. One of the applications of photovoltaic generation technology is used in irrigation systems for farming [4]. The use of energy for the supply of irrigation systems is of great importance for crop production [5]. Even though there are several sources of energy to turn on

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motors, the usage of the sunlight as an alternate energy source. Among these solar panels is quite effective in rural areas as it produces direct current from sun radiations [2].

There are many separately studies that have been carried out of rainwater harvesting and solar irrigation worldwide, but integration of these systems are neglected. Researches have been made on the determination of rainwater harvesting potential; in central Italy [6], Sydney [7], Southwest Nigeria [8], Khartoum [9], Kleinmond [10], Namibia [11], Sylhet City [12], Uganda [13], Middle East [14], Metro Manila [15], Northern Taiwan [16] and Nagpur (17). On the other hand, solar irrigation systems in Turkey [18], Inner Mongolia [19], Brazil [5], India [4], Bangladesh [20], Jalgaon [2], Dangila [21] have been studied. Most of the studies carried out are not about economic analysis. The aim of this study was to determine the cost assessment of rainwater harvesting system for agricultural irrigation in the low rainfall and less radiation areas. Instead of conventional energy sources; monocrystalline, polycrystalline and amorphous silicon solar power based irrigation systems were compared.

MATERIAL AND METHODS

To accomplish the objective specified; rainfall amount, rainwater catchment areas, water storage tank and solar radiation data are described in the following sections.

1. Case study of combined rainwater harvesting with solar irrigation. Rainwater harvesting with solar irrigation system consists of a rainwater collection part, water storage tank, filter unit, pump and irrigation facilities. The solar irrigation used in the study can be divided into three types. Irrigation types consist from monocrystalline, polycrystalline or amorphous silicon solar power, shown in Fig 1.

Figure 1. Combining the rainwater harvesting with solar irrigation

2. Study area. High agricultural production has no direct relationship with high rainfall event. It is very important to have good distribution of the rainfall events along the growing season. Storage of rainfall that occurred at different times during the year can help to supply of water for irrigation in urban areas. Therefore, arid regions were taken in hand as a reference sample where evaporation is greater than rainfall. Annual rainfall in the arid areas is between 50 to 700 mm [22]. Thus, the estimated locations have 50, 200, 350, 500 and 700 mm mean annual rainfall. Stored water was calculated for 50 m^2 roof areas [23].

3. Calculation of rainwater harvesting. The emphasis of this study is on roof based rain water harvesting potential. The volume of harvested rainwater was calculated as follows.

The coefficient of runoff (*Cr*) for any catchment is defined as the ratio of the volume of water that runs off to the volume of rain that falls on to the surface [1].

$$Cr = \text{Volume of Run off} \,/\, \text{Volume of rain water that falls on the surface} \tag{1}$$

The runoff coefficient has been taken as 0.8 which is taken as a standard for the designing of asbestos roof catchment system [1].

Potential of rainwater supply was calculated by using the formula given below [1].

$$S = R \cdot A \cdot Cr \tag{2}$$

Where:
R [m] - mean annual rainfall,
A [m^2]- catchment area,
Cr [-] - coefficient of run off.

4. Solar energy production. The output of a solar array depends on the type of panels used, the amount of sunshine and atmospheric conditions. The maximum performance values and area requirements of the various solar panels are given in Tab. 1 [24].

Table 1. Performances and required area for solar panel types

Panel type	*Max. performance [%]*	*Area [m^0/kWp]*
Monocrystalline	*15*	*9*
Polycrystalline	*14*	*10*
Amorphous silicon	*7*	*20*

5. Estimating system costs and financial cost savings. The economic analysis is carried out through estimating financial cost. The three systems represent using monocrystalline or polycrystalline or amorphous silicon solar power based irrigation is compared (Fig. 2). The aim of the comparison is to find which option is financially more attractive and the criterion of economic feasibility is the ratio of benefits to costs. Market price is used to value the financial cost.

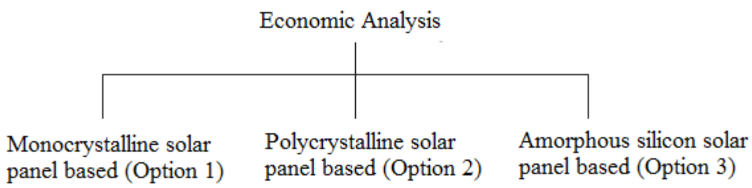

Figure 2. Economic analysis of solar power based irrigation systems

RESULTS AND DISCUSSION

Considering the evapotranspiration of grown products, stored water could use in the most appropriate time. Stored water from the samples was estimated between 2000 to 28000 liters (Tab. 2). Tank size is the most important factor affecting the total cost.

All countries have more or less solar energy potential as an alternative source. Therefore, less radiation areas were selected to be reference sample. The estimated locations have 500, 800, 1100, 1400 and 1700 KWh·m^{-2}-year radiation intensity. The solar panels convert this radiation to electrical energy. Within this study, power of the pump was met by the various solar panels. Solar panels that are used for powering water pump should be set to collect the maximum amount of energy, when water demands are greatest. Energy production due to solar panels and radiation intensity is given in the Tab. 3.

Table 2. Estimate of Potential Rainwater Harvesting

Mean annual rainfall [mm]	*Potential rainwater supply [m^2]*	*Stored water [l]*
50	0.050 x 50 x 0.8	2000
200	0.200 x 50 x 0.8	8000
350	0.350 x 50 x 0.8	14000
500	0.500 x 50 x 0.8	20000
700	0.700 x 50 x 0.8	28000

Table 3. Solar energy production

Radiation intensity [KWh·m^{-2}-Year]	*Energy production from solar panels*		
	Monocrystalline	*Polycrystalline*	*Amorphous silicon*
500	75	70	35
800	120	112	56
1100	165	154	77
1400	210	196	98
1700	255	238	119

Tab. 4 shows the results of economic analysis of the three types of rainwater harvesting systems, in which the present values of all effects (rainwater collection part, polythene water storage tank, 0.75 kW pump, filter unit, irrigation facilities and 1kW solar panel system and components) are calculated. Although the most efficient panels are monocrystalline, polycrystalline panels are rifer in the market and cheaper. Thus, usage of this panel is significantly lower costs.

Table 4. Economic Analyses

	Mean annual rainfall [mm]				
	50	200	350	500	700
Monocrystalline solar panels	2054 $	2948 $	4299 $	5155 $	6612 $
Polycrystalline solar panels	1994 $	2888 $	4239 $	5095 $	6552 $
Amorphous silicon solar panels	2834 $	3728 $	5079 $	5935 $	7329 $

CONCLUSIONS

The water availability problem and the potential for potable water savings by using rainwater harvesting have been assessed. Farmers are suffering from water shortages. Application of rainwater harvesting systems can minimize the water crises and provide water for irrigation. Also, energy need of the pump meet by solar panels which contribute to cleaner production.

This study presents an economic analysis of rainwater harvesting with solar irrigation. Three different solar power based irrigation systems were compared. All solar powered irrigation systems cost huge because of primary investment. However, the results of the economic analysis show that high efficiency and low price because of the widespread usage of monocrystalline and polycrystalline panels have advantageous position against to amorphous silicon. In addition, to obtain most economic return, it is necessary to choose suitable crops and growing patterns.

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PROCENA TROŠKOVA KOMBINOVANJA SAKUPLJANJA KIŠNICE SA SOLARNOM IRIGACIJOM

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Sažetak: Dostupnost vode postaje otežana širom sveta. Povećane potrebe za vodom povećale su interesovanje za različitim sistemima. Sakupljanje kišnice je jedan od načina koji obećavaju zadovoljenje potreba za vodom za navodnjavanje u poljoprivredi. Prenos vode od izvora do parcela zahteva energiju. Postoji nekoliko načina za pogon sistema za navodnjavanje. Jedna od opcija je upotreba solarnih panela kao alternativnog izvora energije koji se koristi tamo gde nema električne energije. Ovaj rad predstavlja analizu sakupljanja kišnice sa navodnjavanje sa monokristalnim, polikristalnim ili amorfno-silikonskim solarnim pogonom sistema za navodnjavanje. Rezultati su pokazali da su za svako navodnjavanje sa solarnim pogonom bili veliki troškovi zbog velikih primarnih ulaganja. Ipak, potrošnja fosilnih goriva može da bude smanjena upotrebom solarnih panela i ovo može da bude rešenje za sadašnju energetsku krizu.

Ključne reči*: sakupljanje kišnice, solarni paneli, ekonomski troškovi*

Prijavljen: *Submitted*:	05.05.2015.
Ispravljen: *Revised*:	10.08.2015.
Prihvaćen: *Accepted*:	14.11.2015.

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Godina XL
Broj 4, 2015.
Strane: 81 - 88

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Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 81 - 88

UDK: 621.83: 669.718

Originalni naučni rad
Original scientific paper

INVESTIGATION OF THROUGH POROSITY OF OXIDE CERAMIC COATINGS FORMED BY PLASMA ELECTROLYTIC OXIDATION

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Abstract: The article presents the results of investigation of through porosity of oxide ceramic coatings obtained by plasma electrolytic oxidation (PEO) on the aluminum parts surfaces, restored by soldering. The optimal modes and electrolyte composition for plasma electrolytic treatment of the restored surfaces are recommended to obtain oxide ceramic coatings with minimum through porosity and high coating and corrosive resistance.

Key words*: plasma electrolytic oxidation, micro arc discharges, current density, electrolyte*, *coating, through porosity, corrosive resistance, high temperature soldering, flux*

INTRODUCTION

Development of the environmentally friendly technologies of high capacity coatings application for parts hardening to increase their corrosive wear resistance is one of the most vital tasks of the modern science and technique [1-6].

Among new methods of creation multifunctional ceramic similar modified coatings with wide property complex, plasma electrolytic oxidation (PEO) is of special interest. The key point of plasma electrolytic oxidation (PEO) is in the formation of the thin layer wear resistant oxide ceramic coating consisting mainly of solid phase aluminum oxides [6-9] on the part surface under the conditions of influence of micro plasma discharges. Plasma electrolytic oxidation (PEO) allows formation of the coatings with 0,3 mm thickness on the complex profiled articles, internal surfaces and hidden cavities, with adhesion comparable with strength of base material [10-12].

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It is known that the mechanical properties of ceramics essentially depend on its porosity. At porosity equal to 5%, tension capacity decreases by 20-40% in comparison with non-porous material [9]. The ceramic coatings anticorrosion properties also depend on the number of through pores in a coating.

Mechanism of oxide ceramic coatings formation by the PEO method determines the presence of through and closed pores in them [9,12]. To a great extent, coatings porosity is influenced by two main factors: capacity of micro arc (micro plasma) discharges, provided by current density and electrolyte composition. Porosity also can be caused by inherent stresses, taking place at crystallization as the result of the difference of thermal coefficient of linear expansion of a base and a coating. At that, most probable is the presence of open porosity than the closed one. [12-13]. Pores reduce the cross sectional area and act as stress concentrators that at exploitation result in more intensive wear of a coating and decrease of its anticorrosion properties. The majority of scientists stress that the oxide ceramic coatings being formed by PEO on the aluminum alloys have porosity from 2% to 14% [4,5,12]. The information about porosity of coatings obtained by PEO on the parts restored by soldering is not presented in the literature.

At plasma electrolytic treatment of parts the weakly alkaline electrolytes on the KOH base with liquid glass additives Na_2SiO_3. are most advanced. The analysis of the phase composition of coatings obtained in the electrolyte of type «KOH-Na_2SiO_3.» shows that the higher the electrolyte content the more silicon compounds are observed in the hardened layer [5,9,10]. It is known that the silicon compounds have considerably lower temperature of melting and evaporation than aluminum oxide. Thus, varying the PEO modes and concentration Na_2SiO_3 in electrolyte, it is possible to a great degree influence on the porosity of the being formed oxide ceramic coatings. Obviously that the less porous coatings will be formed at low current densities and maximum liquid glass concentration (Na_2SiO_3), for the sake of filling cavities between crystals of aluminum oxide with silicon oxide.

The results of the investigation of the through porosity of the oxide ceramic coatings obtained by PEO at different modes and electrolyte composition, on the parts surfaces formed by high temperature soldering are presented below.

MATERIAL AND METHODS

The cylindrical samples (Fig. 1) made of aluminum alloy AK9h (АК9ч) (GK-AlSi10Mgwa) are used for investigations. The material chose is based on the fact that the mentioned alloy is applied for production of great variety of part nomenclature of agricultural machinery and engines cooling system. To form the surfaces on the samples by soldering, aluminum solder of brand SA-12 (ПА-12) (TU 48-17228138/OPP-020-2003) (ТУ 48-17228138/ОПП-020-2003), that is used for soldering the parts operating in corrosion severe conditions and also flux FA=40 (ФА-40) (TU - 4817228138/OPP-019-2003) (ТУ-4817228138/ОПП-019-2003) were used. The content of principal elements in the aluminum alloy and solder is presented in Table 1.

High temperature flame soldering was done on hydrogen-oxygen installation «Energia 1,5». The thickness of the soldered metal layer was 2…3 mm.

Before plasma electrolytic treatment the samples were subjected to grinding. Plasma electrolytic treatment of the coatings obtained by the soldering were done in electrolyte of type «KOH-Na_2SiO_3» on installation *PEO*, operating in the anode-cathode mode (Fig. 2). Concentration *C* of liquid glass in the electrolyte was varied in the range of 3-15 $g \cdot l^{-1}$ of distilled water. Current density D_c was changed from 10 to 30 $A \cdot Dm^{-2}$.

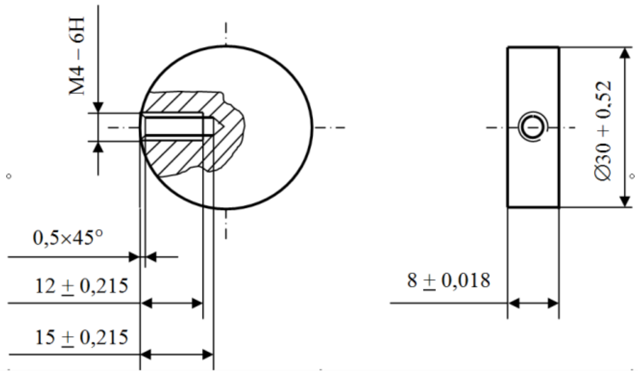


Figure 1. General view of the sample to study through porosity of coatings

Table 1. Content of principal elements (%) in the aluminum alloy and solder (base-aluminum)

Fe	*Si*	*Mn*	*Ni*	*Al*	*Cu*	*Pb*	*Mg*	*Zn*	*Sn*	*Doping material*
Aluminum alloy AK9h (GK-AlSi10Mgwa)										
to 1	*8,0-10,5*	*0,2-0,5*	*to 1*	*86,94-91,63*	*to 0,3*	*to 0,05*	*0,17-0,3*	*to 0,3*	*to 0,01*	*total 1,6*
Solder SA-12										
–	*10-13*	*0,5*	–		*0,6*	–	–	*0,3*	–	–

a. *b.*

Figure 2. General view of installation for PEO
a. electrolytic bath; b. unit of power supply and control

Through porosity of the coatings was determined by the planimetering method [9]. After oxidation and removing the loose layer the samples were washed in distilled water, then they were plunged for 0,5 min into warm (35-40°C) solution NaOH (20 $g \cdot l^{-1}$) and 1 min into clarification solution (nitrogen and fluorohydrogen acids, in the ratio 1:1). Prepared in such a way samples were placed for 5 min into the solution containing 20 $g \cdot l^{-1}$ $CuSO_4$ and 20 $ml \cdot l^{-1}$ HCl. The washed and dried samples with pink spots areas of contacting released copper were examined under the microscope (^{x}20). Through porosity of coatings was estimated in per cent of the measured length area.

RESULTS AND DISCUSSION

The preliminary investigations showed that concentration KOH in electrolyte at the rest constant parameters of PEO, does not sufficiently influence on the porosity of the coatings obtained on the soldered surfaces. That is why, to provide the maximum thickness of the hardened layer is necessary to consider the KOH content in electrolyte constant and equal to 3 $g{\cdot}l^{-1}$.

Te change of concentration Na_2SiO_3 in electrolyte from 3 to 15 $g{\cdot}l^{-1}$, results in reduction of through porosity of the oxide ceramic coatings (Fig. 3, 4). The minimum porosity of coatings is provided at the concentration of liquid glass – 9-12 $g{\cdot}l^{-1}$ of solution. When concentration Na_2SiO_3 in electrolyte is more than 12 $g{\cdot}l^{-1}$, the increase of coatings porosity is observed. Obviously, it is connected with the changes of quality parameters of the process: micro arc discharges are changed by more powerful arc discharges, resulting in gradual destruction of the coating being formed. Such a feature is typical for the coatings of the majority of aluminum alloys, oxidized in electrolyte of type «KOH-$Na_2SiO_{3.}$» [4-10, 12, 14].

The current density at PEO also influences on the through porosity of the formed oxide ceramic coatings (Fig. 3). The least porous coatings are formed at low current densities. It is obvious from Fig. 3 that for oxidation of aluminum samples with the layers soldered in electrolyte of type «KOH-$Na_2SiO_{3.}$», the area of the maximum rational current densities is in the range 15-22 $A{\cdot}Dm^{-2}$. Oxidation of the samples less than 15 $A{\cdot}Dm^{-2}$ is irrational, because of low efficiency of the process and considerable increase of duration of *PEO*. The current density increase of more than 22 $A{\cdot}Dm^{-2}$ at the first stage of *PEO* results in the process intensification. But later powerful spasmodic micro arc discharges that result in the coatings destruction are observed.

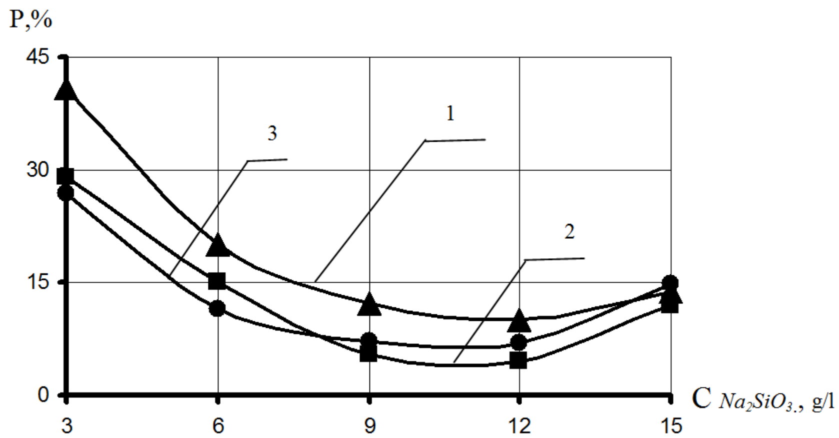
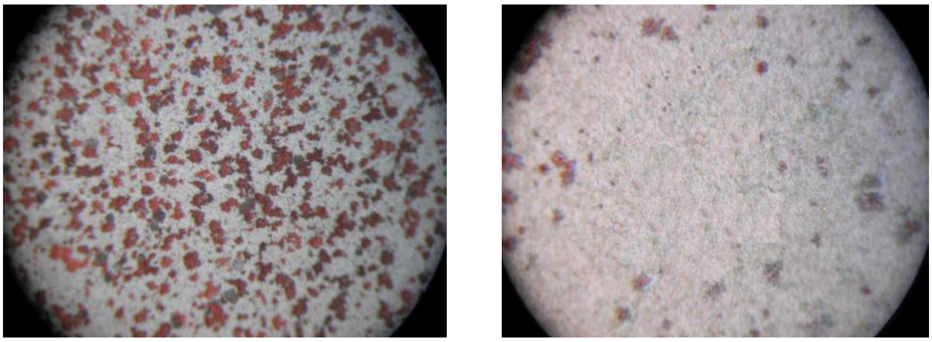


Figure 3. Influence of concentration Na_2SiO_3 and current density on coatings porosity, obtained by PEO in different cutting modes during 120 min:
1. D_c=10$A{\cdot}Dm^{-2}$, 2. D_c=20$A{\cdot}Dm^{-2}$, 3. D_c=30$A{\cdot}Dm^{-2}$



a. *b.*

Figure 4. General view of the coatings of the samples with typical areas of released copper at different modes of PEO:
a. $D_c = 20\ A{\cdot}Dm^{-2}$; $t=20^oC$; $T=120\ min$; $C_{KOH}=3\ g{\cdot}l^{-1}$; $CNa_2SiO_3=3\ g{\cdot}l^{-1}$,
b. $D_c = 20\ A{\cdot}Dm^{-2}$; $t=20^oC$; $T=120\ min$; $C_{KOH} = 3\ g{\cdot}l^{-1}$; $CNa_2SiO_3=10\ g{\cdot}l^{-1}$

Investigating the influence that is produced by the duration of *PEO* and at the rest constant parameters of the process, it is possible to stress that the least porous oxide ceramic coatings are being formed during 1,5-2,0 hours (Fig. 5). For the specified period the formation of the sound coatings are practically completed. The excess of the specified time range results in appearance of more powerful micro arc discharges, increasing the porosity of the hardened layer and also increase of energy consumption.

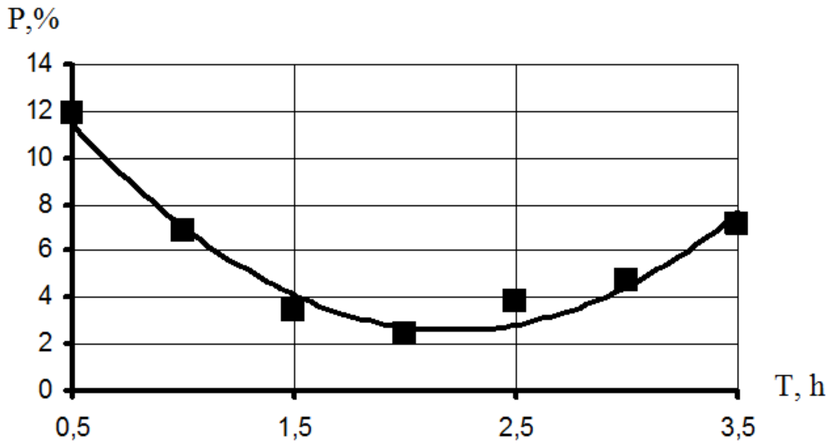


Figure 5. PEO duration influence on through porosity of the coatings:
$D_c =20A{\cdot}Dm^{-2}$; $C_{KOH} = 3\ g{\cdot}l^{-1}$; $CNa_2SiO_3=10\ g{\cdot}l^{-1}$

It was proved in the research that with the electrolyte temperature increase t at the rest constant parameters of *PEO*, through porosity of the coatings increases (Fig. 6). It is connected with the fact that with the electrolyte temperature increase the dissolution rate of metal base and the formed coating in dielectric weak points. For electrolyte of type «KOH-Na_2SiO_3.» the optimal temperature to obtain semi porous coatings is about 18-

25ºC. Oxidation of coatings in electrolyte with the temperature less than 18ºC is irrational, because the powerful cooling system of electrochemical bath is required.

The example of practical usage of oxide ceramic coatings obtained by *PEO* on the worn parts surfaces, preliminary being restored by soldering is presented in Fig. 7.

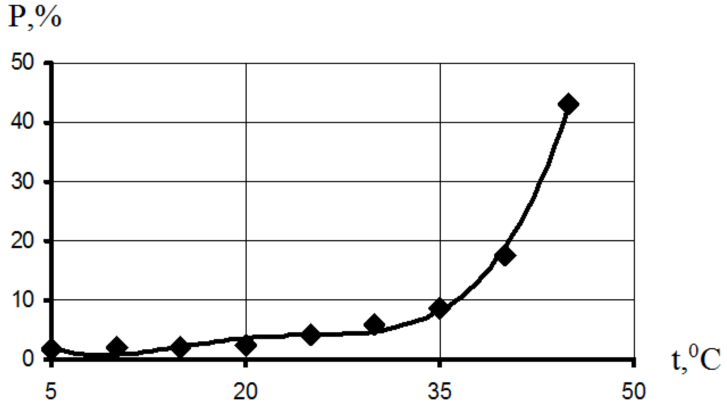


Figure 6. Influence of electrolyte temperature on through porosity of coatings:
D_c =20A·Dm^{-2}; T=2h; C_{KOH} = 3 g·l^{-1}; CNa$_2$SiO$_3$=10 g·l^{-1}

a. *b.*

Figure 7. Cover of engine timing gears ZMZ-53:
a. with the worn surface underneath water pump vane,
b. with surface underneath water pump vane, being restored by soldering and being hardened by PEO

CONCLUSIONS

Based on the research results and to form oxide ceramic coatings with minimal through porosity on the surfaces, obtained on aluminum alloys by high temperature soldering, the following modes of plasma electrolytic oxidation were recommended: current density - 15-22 A·Dm^{-2}, process duration - not less than 120 min. As an electrolyte for PEO, the solution of the following composition is recommended to apply (g·l^{-1} distilled water): KOH – 3; Na_2SiO_3 – 9-12. Operation temperature of electrolyte at oxidation must be kept in the range of 18-25ºC. In the abovementioned modes the thickness of the hardened oxide ceramic layer is not less than 120-150 µm, and its through porosity – not less than 4-6%.

The similar technology of formation of corrosive wear resistant coatings, can be applied at restoration and hardening of worn parts produced from aluminum and its alloys, operating in the conditions of different corrosive environment.

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ISPITIVANJE POROZNOSTI OKSIDNIH KERAMIČKIH PREVLAKA NANETIH PLAZMA ELEKTROLITIČKOM OKSIDACIJOM

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Sažetak: U ovom radu su predstavljeni rezultati ispitivanja unutrašnje poroznosti oksidno keramičkih prevlaka nanetih plazma elektrolitičkom oksidacijom (*PEO*) na površine aluminijumskih delova, restauriranih lemljenjem. Za optimalne elektrolitičke sastave za plazma elektrolitički tretman restauriranih površina preporučene su oksidne keramičke prevlake sa minimalnom unutrašnjom poroznošću, visokom pokrivenošću i otpornošću prema koroziji.

Ključne reči: *plazma elektrolitička oksidacija, mikro lučna pražnjenja, gustina struje, elektrolit, prevlaka, unutrašnja poroznost, otpor prema koroziji, visoko-temperatursko lemljenje, fluks*

Prijavljen:
Submitted: 22.05.2015.
Ispravljen:
Revised:
Prihvaćen:
Accepted: 12.10.2015.

Univerzitet u Beogradu
Poljoprivredni fakultet
Institut za poljoprivrednu tehniku
Naučni časopis
POLJOPRIVREDNA TEHNIKA
Godina XL
Broj 4, 2015.
Strane: 89 - 94

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 89 - 94

UDK: 620.91

Originalni naučni rad
Original scientific paper

ENERGY PRODUCTIVITY OF PHOTOVOLTAIC CELLS IN NITRA

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Abstract: This contribution is oriented to measurement and evaluation of the obtained energy from photovoltaic cells efficiency in practice conditions. Photovoltaic cells were monitored during one year in Nitra, Slovakia. Cells are monocrystalline with surface 1.95 m^2 and in full measurement time are directed perpendicular to the sun rays. Tracking and stationary systems were used for results evaluation. Six cells per system are used in the combined serial-parallel connection. Output energy from both systems is 496.257 kWh. Price of obtained energy is 69.48 EUR for actual price of electric energy, which is 0.14 EUR per kWh. The output power of the photovoltaic tracking system was higher by 20.39% opposite to stationary system.

Key words*: solar cell, solar tracker, tracking systems, polycrystalline cell*

INTRODUCTION

Converting of solar energy to electrical energy by photovoltaic cells is popular in this time. There are two basic types of photovoltaic cells – monocrystalline and polycrystalline. Theoretical efficiency of monocrystalline cell varies from 11.5 to 16 %. Polycrystalline cell has efficiency up to 14 %. Assuming that efficiency of the quality of collectors based on crystalline silicone is about 18 ÷ 20 % [1]. Cell is working on the base of the photovoltaic effect, firstly observed by physicist A. E. Becquerel in 1839. The photovoltaic effect is the creation of voltage in a material upon exposure to light [2]. The mostly used material for convert of solar energy to electrical is semiconductor P-N junction.

Our measurement system is placed on the roof of Renewable energy sources laboratory of Department electrical engineering, automation and informatics in Nitra. Latitude of GPS location of laboratory is 48°18’9.484’’ north and longitude is 18°5’43.96’’ east. Altitude is 137 m. Obtained energy is used for heating and lighting of

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laboratory. System is monitored 24 hours a day. Various tracking algorithms were tested on tracker.

MATERIAL AND METHODS

Used cells STP040S – 12/Rb are developed by SUNTECH. Total efficiency 12.6 % with a 25 years warranty is specified in the manufacturer's datasheet. Optimal operating voltage is 17.6 V and optimal current is 2.56 A. Maximum power is 45 Wp (1000 W·m^{-2}) and operating temperature is from -40 to +85 °C. The cells are produced from monocrystalline silicon. Six cells are used in the combined serial-parallel connection as shown in Fig. 2. Active surface of cells is 1.95 m^2. The temperature coefficients declared by manufacturer are shown in Tab. 1.

Table 1. Declared temperature coefficients of PV module STP040S – 12/Rb

Nominal operating cell temperature	*45 °C*
Short-circuit current temperature coefficient	*(0.055 ± 0.01) % / K*
Open-circuit voltage temperature coefficient	*-(78 ± 10) mV / K*
Peak power temperature coefficient	*-(0.48 ± 0.05) % / K*
Power tolerance	*± 5 %*

The pyranometer SG002 was used for the measurement of global solar radiation intensity. The measurement is based on the principle of temperature difference, which is created on black and white surface. Thermocouplers are used for temperature measuring of these surfaces. Pyranometer is situated on the tracker. Therefore, value of the global radiation intensity is not distorted by azimuthal error. The pyranometer is thermally isolated from the metal construction and it is placed in the sufficient distance to minimize the thermal impact. Technical parameters of used pyranometer are in Tab. 2 and its design is shown in Fig. 1.

Table 2. Technical parameters of the pyranometer SG002

Measuring range, W· m^{-2}	*0 – 1200*
Spectral range, μm	*0.3 – 3*
Output voltage, V	*0 – 2*
Power supply, V	*18 – 30*
Response time, s	*50*
Operating temperature, °C	*-30 – +60*
Minimal load impedance, Ω	*500*
Error, %	*± 3*

The temperatures are measured by calibrated digital temperature sensors DS18B20. Communication between control microprocessor and sensors is realized by 1-wire protocol. Standard accuracy is ± 0.5 °C in temperature range from -10 to + 85 °C. Accuracy is better than 0.25 °C in temperature range from – 10 to + 100 °C. The temperature sensors were additionally calibrated for this range.

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Figure 1. Pyranometer SG002

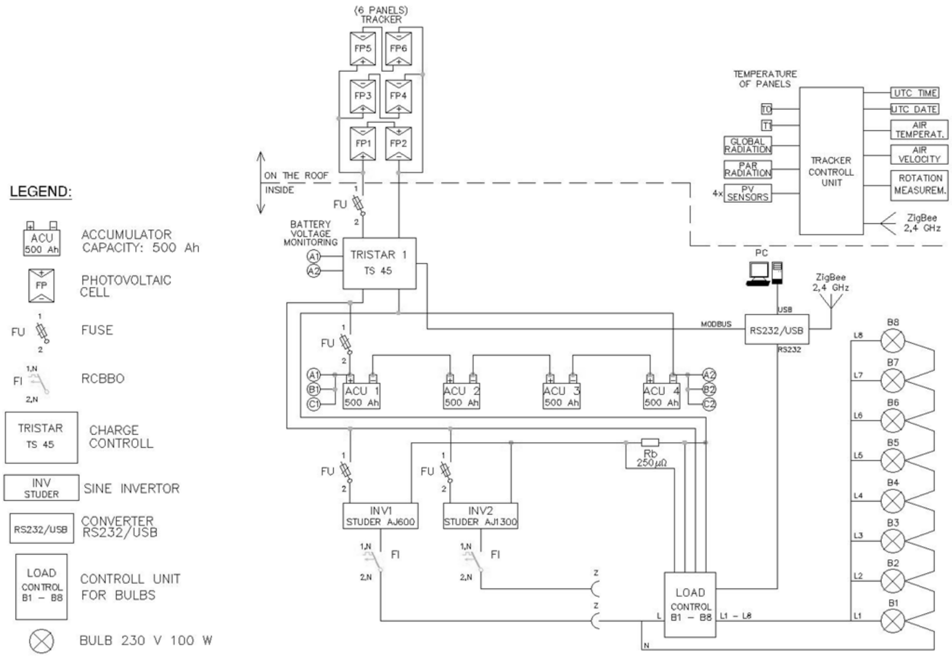

Figure 2. Block diagram of connection

TriStarTM controller TS-45 is used for battery charging. The controller operates in one mode at the time. Rated solar current of the controller is up to 45 A and system voltage is set to 24 V in our case. Accuracy of the voltage measurement is lower than 0.1 % ± 50 mV. Modbus communication protocol was used. Communication is realized on the RS-232C physical layer.

System is loaded by bulbs, which are switched by the module Load Control (Fig. 2). Output current of system and battery voltage is measured by this module. Converter resolution is 12-bit. The sine wave inverter AJ1300 was used. Its manufacturer is STUDER company. Maximum output apparent power is 1300 VA and efficiency is up to 95 %. Input voltage is optimally 24 V. Inverter output voltage is sine waveform with effective value 230 V / 50 Hz, it is generated by the *PWM* principle with passive filtration.

The measurement system is controlled by the single-chip microcontroller modules. Data are recorded by the program in Labview via *USB* port as shown in Fig. 2. Measurements are saved to data files in Matlab structure (*.dat) for suitable results evaluation.

RESULTS AND DISCUSSION

Collected energy from system was approximately equal to supplied energy during the measurement. Therefore, battery voltage was regulated to 26 V. Constant battery voltage is controlled by the program in Labview. The basic role of load control module is regulation of output power. System is based on the industrial single-chip microcontroller C8051F340, which was manufactured by Silicon Laboratories. All important parameters were monitored and saved to the file, namely: cells output voltage, cells output current, battery voltage and load current. These data are necessary for energy relationship calculation. The amount of electric energy was calculated based on data from whole year of systematic measurement. Acquired energy for individual months is presented in Tab. 3.

Table 3. Calculated data of electric energy amount, global radiation and efficiency

Month	*Tracking system output energy [kWh]*	*Stationary system output energy [kWh]*	*Global radiation [kWh·m^{-2}]*	*Efficiency of tracking system [%]*	*Efficiency of stationary system [%]*
May	*33,12*	*28,10*	*266,50*	*12,43*	*10,54*
June	*53,61*	*37,88*	*379,43*	*14,13*	*9,98*
July	*59,26*	*44,35*	*429,22*	*13,81*	*10,33*
August	*52,14*	*38,49*	*369,53*	*14,11*	*10,41*
September	*29,59*	*25,76*	*237,90*	*12,44*	*10,83*
Oktober	*27,43*	*25,40*	*223,53*	*12,27*	*11,36*
November	*21,15*	*19,99*	*168,11*	*12,58*	*11,89*
Average	*39.47*	*31.42*	*296.32*	*13.11*	*10.76*

Fig. 3 shows the comparison of the produced electric energy amount between static solar panels and tracker solar panels, which are placed in the above mentioned photovoltaic power plant. For the data processing were used records collected during time period from May to November in 2013.

The produced electric energy amount during this period is calculated in kWh per month. In total, during this monitoring period the amount of produced electric energy was 276.29 kWh for tracker solar panels and 219.967 kWh for static solar panels, respectively. As it can be seen, the energy produced by tracker solar panels is greater than power produced by static solar panels. But that difference depends on period of the year. The difference was the highest during the summer sunny days in July; the maximum value of electric energy was 59.290 kWh per month for tracking system and 44.349 kWh per month for stationary system. Insignificant difference was found in May, September, October and November. However, visible and significant difference was found in June, July and August. This probably corresponds to length of sunlight, which falls directly to tracker in summer period. On the contrary, the curves are approximate in wintertime, which means that diffuse radiation is used equally. This can be confirmed with values in November, where almost no difference was found. It is depending on the diffuse radiation quantity. The tracking system produces 21.148 kWh per month, which is very close to 19.986 kWh per month produced by stationary system.

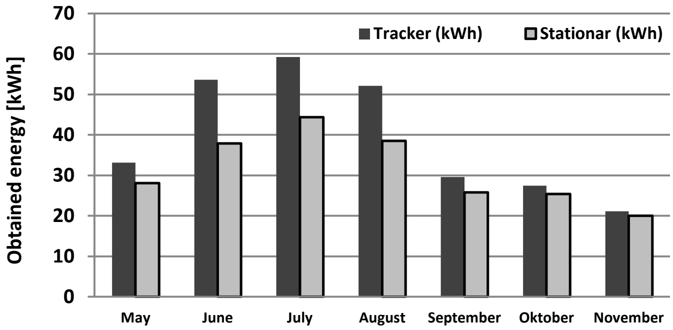

Figure 3. Comparison of the obtained amount of electric energy between static solar panels and tracker solar panels

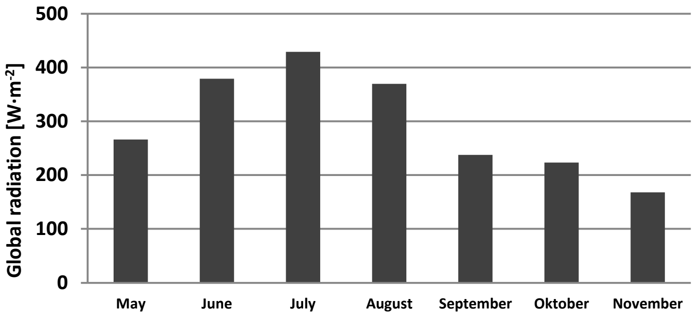

Figure 4. Global radiation from May to November

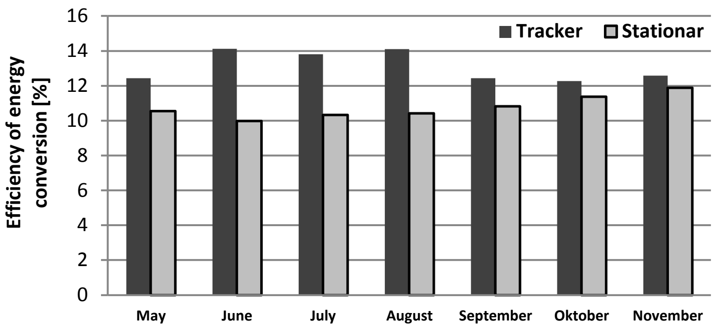

Figure 5. Efficiency of energy conversion in %

Fig. 4 shows global radiation and efficiency for every month individually, during the period from May to November 2013. There is big difference between individual months, for example in August was the global radiation 369.529 $kWh \cdot m^{-2}$ compare to September where it was only 237.895 kWh·m^{-2}. There were more rainy days in Central Europe during the September 2013 and that is the reason, that the global sun radiation is lower.

Efficiency of tracker and six static solar panels is presented in Fig. 5. Efficiency of photovoltaic solar system can be significantly increased with using of tracking position system from May to September. Higher efficiency is caused by minimal evidence of solar diffuse radiation.

CONCLUSIONS

The output power of the photovoltaic tracking system was higher by 20.39 % opposite to stationary system according to described conditions in time from May to November at year 2014. Maximum efficiency of tracking system was 14.13 % in June. Produced energy by tracking systems was 276.29 kWh at mentioned period. Output energy from stationary system was 219.967 kWh. Same type of photovoltaic cells is used in both systems. Output energy from both systems is 496.257 kWh. Price of obtained energy is 69.48 EUR for actual price of electric energy, which is 0.14 EUR per kWh.

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ENERGETSKA PRODUKTIVNOST FOTONAPONSKIH ĆELIJA U NITRI

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Sažetak: Ovaj rad se bavi merenjem i ocenom efikasnosti dobijene energije iz fotonaponskih ćelija u praktičnim uslovima. Fotonaponske ćelije su bile praćene tokom jedne godine u Nitri, Slovačka. Ćelije su monokristalne, površine 1.95 m^2 i tokom punog merenja usmerene upravno na sunčeve zrake. Za ocenu rezultata su korišćeni praćenje i stacionarni sistemi. Šest ćelija po sistemu su upotrebljene u kombinovanoj serijsko-paralelnoj vezi. Izlazna energija iz oba sistema je 496.257 kWh. Cena dobijene energije iznosi 69.48 EUR po trenutnoj ceni električne energije, što je 0.14 EUR za 1kWh. Izlazna snaga fotonaponskog sistema praćenja bio je viši za 20.39% u poređenju sa stacionarnim sistemom.

Ključne reči*: solarna ćelija, solarni tragač, sistemi za navođenje, polikristalna ćelija*

Submitted: 16.04.2015.
Revised:
Accepted: 17.10.2015.

Univerzitet u Beogradu
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Godina XL
Broj 4, 2015.
Strane: 95 - 99

University of Belgrade
Faculty of Agriculture
Institute of Agricultural Engineering
Scientific Journal
AGRICULTURAL ENGINEERING
Year XL
No. 4, 2015.
pp: 95 - 99

Co-funded by the Tempus Programme of the European Union

CaSA

TEMPUS PROJECT PRESENTATION

Project title: BUILDING CAPACITY OF SERBIAN AGRICULTURAL EDUCATION TO LINK WITH SOCIETY Acronym: “CaSA”

Part 3. COURSES AND NaRA

544072-TEMPUS-1-2013-1-RS-TEMPUS-SMHES
(2013 – 4604 / 001 - 001)
Sub programme:
Structural Measures, Action Higher Education and Society

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INTRODUCTION

This is a presentation of the CaSA project and the role it plays in linking research and innovation with knowledge improvement in agriculture. CaSA is a national project, coordinated by The University of Belgrade, Faculty of Agriculture.

It belongs to the TEMPUS sub-program Structural measures and the Action Higher education and society. These two benchmarks point out what are the main objectives of the project: to improve quality and availability of vocational agricultural education; to strengthen competences of educators; to create a National Repository for Agricultural Education (NaRA) [3].

Basic course is strengthening links between higher education (HE) and society by building capacity of Serbian:

- University teachers from Faculties of Agriculture (FA)
- Agricultural secondary school (AMS) teachers
- experts in Extension services (ES)

to improve teachers' competences in pedagogic skills and provide in-service vocational training courses.

Specific objectives of the project are:

- SO1 - Improvement of quality and availability of vocational agricultural education
- SO2 - Strengthening of professional and pedagogical competences of educators
- SO3 - Creation of the "open source" repository for educators in the area of agricultural education

Creation of a National Repository for Agricultural Education (NaRA) - a repository for online courses and teaching resources to ensure project sustainability and networking of all stakeholders in agricultural education.

There are 13 partners contributing to the project, 10 Serbian and 3 EU partner institutions. Serbian partners are 5 agricultural faculties from Belgrade, Novi Sad, Kragujevac, Novi Pazar and Sremska Kamenica, as well as Association of Agricultural Middle School in the area of agriculture, food processing and food production, Institute for Science Application in Agriculture responsible for in-service training of agricultural advisors, 2 NGO training organization (Education Forum and Balkan Security Network) and the Ministry of Education, Science and Technological Development of the Republic of Serbia. EU partners are universities from Timisoara (Romania), Maribor (Slovenia) and Foggia (Italy)

All project activities are grouped into 11 work packages.

The project lasts for 3 years (01/12/2013 - 30/11/2016) and aims to build the capacity of main holders of Serbian agricultural education: university teachers, teachers in agricultural middle schools and agricultural advisors working in extension services.

The CaSA project's main achievement will be the creation of a NaRA, available as an electronic platform that should enable the sustainability of the project and connection of stakeholders involved in all levels of agricultural education and training in Serbia. This repository will include: information necessary for teaching traditional courses as well as online courses for professional development of Agricultural Middle Schools and experts in extension services; databases of results obtained by research; selected and recorded classes of interactive teaching; selected parts of courses realized and/or developed within the project, prepared in the form of online video tutorials and posted together with additional teaching contents; and other relevant contents added to the repository based on authorized decisions of the NaRA Advisory Board.

All project participants have agreed and signed the Constituent agreement on project implementation and NaRA management.

COURSES AND NaRA

Those issues were structured through a lot of activities in different work packages. In the following part are presented the activities, including planned and realized deliverables.

WP 1 - Creation of the Repository
WP leader: Cosmin Salasan, USAMVBT, Timisoara, Romania

A1.2. Creating and maintenance NaRA

From its establishment NaRA will become a National Repository for Agricultural Education, and will be maintained as such during project duration and beyond. Creation and maintenance of the repository will be under the responsibility of project coordinator.

Intensive activities on NaRA organisation, its structure and functionalities were carried out. After several meetings organized with staff of the IT Centre of UB, NaRA domain was registered in July 2014 www.nara.ac.rs.

Decision on NaRA structure was finally decided as follows: Moodle + DSpace software integration as suggested by IT Center of UB. A plug-in was created for connecting Moodle software as an LMS with a DMS such as the already widely used DSpace. The meeting for the Constitution of the NaRA Advisory board was held on February 11 2015 in UB.

WP 4 - Modernization of teaching contents
WP leader: Snežana Tanasković, UNIKG, Čačak, Serbia

A4.3. Development of classical (f2f) vocational courses for AMS teachers and agronomists in extension service

30 University teachers (8 from UBFA, 7 from UNS, and 5 from UNIKG, SUNP and EDUCONS each) will develop classical vocational courses.

A4.4. Development of web based vocational courses

30 University teachers (7 from UBFA, 8 from UNS, and 5 from UNIKG, SUNP and EDUCONS each) will develop online vocational courses.

Both courses are actually registered and courses outlines are under review by EF, commented and corrected by UT before sending the translation to EU partners for review by July 2015.

WP 7 - Pilot implementation of vocational courses
WP leader: Ljubinko Jovanovic, EDUCONS, Sremska Kamenica, Serbia

A7.1. Implementation of classical pilot vocational courses

Classical vocational courses will be held in HE Institutions. 30 AMS teachers and 30 agronomists from ES will take classical vocational courses at 5 Universities.

Implementation of classical pilot vocational courses - foreseen for November 2015 – November 2016.

A7.2. Implementation of pilot web based vocational courses

Web based vocational courses will be offered and taken by 30 AMS teachers and 30 agronomists from ES.

Implementation of pilot web based vocational courses – foreseen for November 2015 – November 2016.

WP 8 - Quality assurance control of project activities

WP leader: Sofija Pekić Quarrie, SUNP, Novi Pazar, Serbia

A8.4. QA of vocational courses – peer review by EU Partners

EU partners will peer review vocational courses and prepare reports with suggestions for courses improvement. When needed the extended abstracts of the courses and methodology used will be translated in English by UT – courses creators.

This is the project major task in 2015. At the Cacak workshop and SC meeting a form of 2 pages courses registration was agreed and workshops with UT at each University were held. Courses registration 2 pages abstract are currently reviewed by EF ("extra" proposal activity agreed among partners to be done before translation and review by EU partners).

A8.5. Development of questionnaires for vocational course evaluation

Questionnaires for vocational courses evaluation will be developed by experts from BSN.

Development of questionnaires for vocational course evaluation by BSN – foreseen for October, November 2015.

A8.6. Analysis of course feedback questionnaires from pilot implementation of vocational courses

Course feedback questionnaires from pilot implementation of vocational courses will be analysed by BSN experts, and report and conclusions prepared.

Analysis of course feedback questionnaires from pilot implementation of vocational courses by BSN – foreseen for February – November 2016.

WP 10 - Exploitation of project results

WP Leader: Predrag Pudja, UB, Belgrade, Serbia

A10.1. Reaching agreement between faculties' managements on: maintenance of NaRA, recognition of teachers work in courses preparation, availability of NaRA content, and courses commercialization

The Agreement reached between managements of the faculties on: maintenance of NaRA, recognition of teachers work in courses preparation, availability of NaRA content, and qualifications commercialization will be prepared during the kick-off meeting, after discussions of all project partners, including EU partners that will contribute to agreement preparation and consensus of Serbian Universities.

After being commented, and improved in communication with all beneficiaries the NaRA Constituent agreement was signed gradually by all project partners.

A10.2. Defining procedures for intellectual property rights of courses creators

Procedures for intellectual property rights of courses creators will be adopted. Previously the draft of procedures will be prepared, discussed and modified where needed.

From the first draft presented at the Kickoff, until Cacak workshop Procedures for Intellectual Property Rights were made available for comments, improved and Revised IPR adopted at the Cacak workshop and SC meeting.

A10.3. Preparation for accreditation of vocational courses for AMS teachers

Vocational courses for AMS teachers prepared for accreditation according to the methodology prescribed by the Institute for Education Improvement.

Preparation for accreditation of vocational courses for AMS teachers is foreseen for November 2015 – January 2016.

A10.4. Preparation for certification of vocational courses for ES experts

Vocational courses for experts from ES prepared for certification at the Ministry of Agriculture.

Preparation for certification of vocational courses for ES experts will be realized November 2015 – January 2016.

CIP – Каталогизација у публикацији
Народна библиотека Србије, Београд

631(059)

ПОЉОПРИВРЕДНА техника : научни часопис = Agricultural engineering : scientific journal / главни и одговорни уредник Горан Тописировић. – Год. 1, бр. 1 (1963)-   . - Београд; Земун : Институт за пољопривредну технику, 1963- (Београд : Штампарија ”Академска издања”) . – 25 cm

Тромесечно. – Прекид у излажењу
од 1987-1997. године
ISSN 0554-5587 = Пољопривредна техника
COBISS.SR-ID 16398594