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DEVELOPMENT AND EVALUATION OF A CONTINUOUS TYPE TAMARIND DESEEDER

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Abstract: A continuous type tamarind deseeder with a capacity of 75 kg·h^{-1} has been fabricated and evaluated at the Department of Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, India. The machine consists of a seed separation unit and separate outlets for the seeds and deseeded fruits. In the seed separation unit, the fruits were subjected to impact and simultaneous shearing force by pegs mounted on the wooden roller to break open the fruit and to push the seeds out of the oblong sieve. After deseeding, the seeds and fruit pulp were collected separately through their respective outlets. The performance of the developed machine was evaluated based on deseeding efficiency. Evaluation was done by conducting experiments at different operating conditions including different moisture content of tamarind fruit (20.0, 22.5 and 25.0% on dry basis) and varying wooden roller speed (2.5, 3.4 and 4.2 m·s^{-1}), feed rate (45, 60 and 75 kg·h^{-1}) and horizontal clearance (14, 16 and 18 mm). The test results of the machine showed that a maximum deseeding efficiency of 89.15% was found at 22.5 percent moisture content on dry basis, with the wooden roller speed of 3.4 m·s^{-1}, feed rate of 45 kg·h^{-1} and 16 mm horizontal clearance. As compared to existing manual methods of deseeding, the continuous type tamarind deseeder unit recorded 93.34 % saving in time and 74.9 % saving in operation cost.

Key words: *Tamarind deseeder, seed separation unit, wooden roller, deseeding efficiency*

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INTRODUCTION

Tamarind (*Tamarindus indica* L.) is native to tropical Africa and is quite common in wild regions. India is the largest producer and consumer of tamarind and producing 2,75,500 tonnes of tamarind annually, and are chiefly subsistence crop for the semi-arid zones of the country. It is generally grown as avenue trees in highways, wastelands, backyards and forestlands [1].

The Tamarind tree bears pods (fruits) containing about 3-10 brown seeds surrounded by an abundant acid pulp. On an average, tamarind fruit contains 55 % pulp, 34 % seeds and 11 % shell and fibres [2]. It is valued mostly for its fruit pulp and seed which are used for a wide variety of domestic and industrial purposes. The edible pulp of a ripe fruit is used as flavouring agent in soups, jams, chutneys, sauces and juices. The fruit pulp is the richest natural source of tartaric acid and is the main acidulant used in the preparation of South Indian foods today. Tamarind juice, concentrate, powder, pickles and paste are the other well-known end products of tamarind processing.

Tamarind processing commonly includes the unit operations of drying of pods, dehulling, deseeding, pressing into cakes and storage. Traditionally, deseeding of tamarind involves manual harvesting of mature fruits which are then sun dried and then the pod is removed from the pulp by beating the dried fruit with sticks. The current practice of tamarind deseeding is to impact the vertically oriented fruits manually with a hammer or wooden mallet by women labourers. It is also deseeded by the process of hand pounding in which a stone mortar is sprayed with oil, generally castor oil, and a wooden pestle is used to exert impact load over the fruits. In some areas, a knife is used to deseed. The conventional methods followed are crude, unhygienic, labour intensive and time consuming. This drudgery can be alleviated by introducing a mechanical deseeder for tamarind [3].

There were few attempts made to deseed tamarind mechanically. The pulp-squeezing unit developed by [4] consisted of a serrated roller mounted on a Mild Steel (MS) frame. Adjoining to the roller, stationery rasp bar was provided. The tamarind was passed through the clearance between serrated roller and rasp bar to separate seed out of pulp. The main drawback is that the mechanical machine has to be stopped intermittently to scrap away the deposits of tamarind pulp over the mechanism. Three different mechanisms [5] to shear and squeeze the tamarind pulp out of seeds such as two wooden identical plain rollers, wooden rasp-bar drum with concave and metal rasp-bar drum with concave were studied. The end-product out of the machines was collapsed and the compartmental arrangement of tamarind was detached. A tamarind seed remover [3] with the principle of impact and simultaneous shear on the tamarind fruit by the pegs mounted rotor that encased with oblong sieve was developed and evaluated for its performance. The machine resulted in 82 % deseeding efficiency for small sized fruits and effective separation of seed and deseeded pulp was the main lacuna observed.

Even though there were few mechanisms studied so far, they have their own pitfalls in popularizing among the farming community. These machines cannot be operated continuously because of the sticky nature of tamarinds with the mechanisms adopted and the collapsed end product is sold at throwaway prices. Final output of the existing deseeding machines is a mixture of pulp and seed and separation of the seed out of pulp is again laborious and time consuming. With the intention of alleviating these constraints in the processing field, a tamarind deseeder was developed and evaluated at the

Department of Food & Agricultural Process Engineering, Tamil Nadu Agricultural University, Coimbatore, India. The paper deals with developmental procedure of tamarind deseeder and evaluation of the machine besides optimization of process parameters like materials used for fabrication, clearance and speed of the unit.

MATERIAL AND METHODS

Development of Tamarind Deseeder

The developed tamarind deseeder consisted of hopper, deseeding unit, outlets and power transmission system and the descriptions of each component are illustrated.

All the components of deseeder were supported over a frame made up of mild steel L - angle section of size 50 x 50 x 6 mm. It has a trapezoidal shape. The size of the frame at the top was 1170 x 410 mm and at the bottom, it was 1170 x 970 mm. The height of the frame was 860 mm from the ground level. The frame was well braced to provide rigidity to mount and support other parts of the machine and to withstand vibrations during operation. A sub frame was made to fix the motor. Two mild steel flats of 5 x 50 mm size were welded on the bottom of the main frame. The space between the two flats was 260 mm. The sub frame was welded to the main frame to provide rigidity and to withstand vibration during operation.

The hopper has rectangular upper and base openings of 300 x 200 mm and 230 x 100 mm, respectively. It was made of 1.5 mm thick mild steel sheet. The main components of the deseeding unit are pegs mounted on wooden roller, concave, cutting blade and drum.

The wooden roller (Fig.1) is an important component of the deseeding machine. It consists of a helical blade (screw auger) to convey the feed and pegs of 80 x 8 mm, fixed on the wooden roller in a zigzag manner for imparting impact load over the fruits. The wooden roller was selected instead of mild steel rotor shaft for easy resizing and modification. Square wood (Botanical name: *Terminalia crenulata*, Tamil name: Karumaruthu) of 17.5 x 17.5 x 1200 mm was sized into a wooden roller of 1070 mm length and 160 mm diameter. At the end of the wooden roller, mild steel round flat (6 mm thickness) plates were fastened with projecting shaft on both sides. In the mild steel round flat plate, the shaft was inserted up to 50 mm inside and 100 mm projected outside. Sleeves were attached at both the ends for a length of 100 mm. Both ends of the wooden roller were supported suitably using two pillow block bearings mounted on the frame. One end of the wooden roller was coupled to the power transmission system.

Pegs were made up of coach screw of size 12.5 x 125 mm. The pegs were inserted in to the wooden roller in a zigzag manner with a projection of 80 mm from the wooden roller. The linear distance between two successive pegs was fixed as 50 mm. The radial angle between adjacent pegs was 90^{o}.

Concave mesh is a semi-circular shaped mesh surrounded below the drum, constructed from a perforated mild steel sheet of 5 mm thickness with a dimension of 600 x 1000 mm. It has oblong holes (openings) of 9 x 25 mm to allow only the seeds to pass through the holes. It was welded at both the sides with a half round mild steel flat sheet of 6 mm thickness and 350 mm diameter at the bottom of the frame.

To make additional impact force during the operation, a mild steel cutting blade of dimensions 50 x 6 x 1050 mm was fixed on the rear end of the wooden roller. It was fixed with an adjustable arrangement through bolt and nuts and the front end was fixed with screw auger.

Figure 1. Wooden roller with pegs

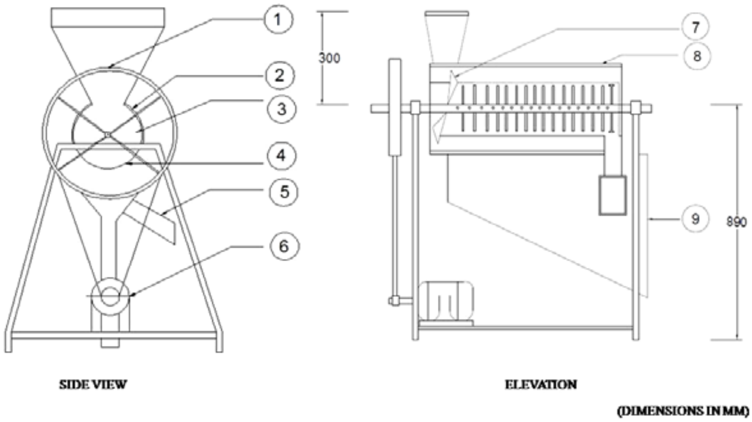

Figure 2. Schematic view of tamarind deseeder
1. feed hopper, 2. outer cover, 3. wooden roller, 4. concave, 5. pulp outlet, 6. motor, 7. screw conveyor, 8. deseeding unit, 9. seed outlet

The screw auger was made out of 6 mm thick and 320 mm diameter of mild steel round flat sheets by cutting and stretching it suitably. The diameter and pitch of the auger were 320 mm and 160 mm, respectively.

Drum was made up of 1.5 mm thick mild steel sheet and it was provided over the entire length of the main frame to enclose the deseeding section. Two semi circular mild steel sheets of 6 mm thick and 152 mm radius were used as enclosure for the deseeding unit. The drum was fixed on the frame by means of nuts and bolts.

After deseeding the fruits, seeds and fruit pulp were collected through separate outlets. The deseeded pulp outlet was made up of a rectangular closed channel fixed below the concave sieve at an angle of 60^o to the horizontal. The seed outlet was mounted on the tool frame below the sieve. The both outlets were made up of 1.5 mm thick mild steel sheet. The partly dismantled tamarind deseeder machine is given in Fig.3.

A pulley of 400 mm diameter was attached at one end of the wooden roller to reduce the speed from 1440 rpm to 280 rpm. A V-belt of 800 mm length was used to transmit the power from the motor to the wooden roller. A five hp three phase electric motor of 1440 rpm was selected. Two dimensional views of tamarind deseeder are given in Fig. 2 and deseeder at working condition is given in Fig.4.

Working principle

Tamarind fruits are fed into the deseeding unit through feed hopper. After the impact load exerted by pegs mounted on wooden roller, the tamarind is ready to shed its seed out of its pulp. Since the impacted fruit is conveyed and sheared simultaneously, the seeds are removed through the concave screen and pulp are conveyed and collected at the separate outlet.

Figure 3. Tamarind deseeder (partly dismantled)

Performance Evaluation of Tamarind Deseeder

The developed tamarind deseeder was tested for its performance under four variable conditions. Three different feed rates *viz.,* 45 $kg{\cdot}h^{-1}$ (F_1), 60 $kg{\cdot}h^{-1}$ (F_2) and 75 $kg{\cdot}h^{-1}$ (F_3), three different moisture contents of tamarind fruits *viz.,* 20 % (M_1), 22.5 % (M_2) and 25 % (M_3) on dry basis with three different rotational speeds of the wooden roller *viz*., 2.5 $m{\cdot}s^{-1}$ (S_1), 200 rpm (S_2) and 4.2 $m{\cdot}s^{-1}$ (S_3) and three concave clearances *viz.,*14 mm (C_1), 16 mm (C_2) and 18 mm (C_3) were considered for optimizing the parameters to get high deseeding efficiency. The effect of processing parameters on deseeding efficiency is presented in the Tab. 1.

Figure 4. Tamarind deseeder (working condition)

Table 1. Number of levels and values of Independent and Dependent variables

Independent Variables	Symbol	Levels	Values	Dependent Variable
Moisture content, % (db)	M	3	25, 22.5, 20	Deseeding Efficiency (%)
Peripheral Speed ($m \cdot s^{-1}$)	N	3	4.2, 3.4, 2.5	
Concave Clearance (mm)	C	3	18, 16, 14	
Feed rate ($kg \cdot h^{-1}$)	F	3	75, 60, 45	

No. of treatments = 3 x 3 x 3 x 3 = 81

Deseeding efficiency

Deseeding efficiency of the newly developed machine was determined by standard procedure [6]. Deseeding efficiency was calculated by the following formula.

$$D.S = \frac{S_1 + S_2}{S_1 + S_2 + S_3 + S_4} X 100 \qquad (1)$$

Where:

$D.S$ [%] - deseeding efficiency,

S_1 [g] - weight of seeds that are collected in the seed outlet,

S_2 [g] - weight of seeds that are collected in the pulp outlet,

S_3 [g] - weight of seeds taken manually from opened fruits,

S_4 [g] - weight of seeds taken in the unopened fruits.

These results were statistically analyzed using Completely Randomized Block factorial design.

RESULTS AND DISCUSSION

The effect of all processing parameters on deseeding efficiency is presented in Tab. 1. Mainly the effect of speed on deseeding efficiency with three different feed rates of 75 $kg \cdot h^{-1}$, 60 $kg \cdot h^{-1}$ and 45 $kg \cdot h^{-1}$, for different moisture content and clearances is depicted in Fig. 5-7.

From Fig. 5, it is noted that the deseeding efficiency was initially increased with increase in moisture content due to little softening of the tamarind fruit and then it gradually decreased with increase in moisture content at different feed rates, speed and clearances. This decrease in deseeding efficiency at higher moisture content is attributed to the fact that at 25%, tamarind fruit becomes very soft. Among the three moisture contents studied, the maximum deseeding efficiency was obtained at 22.5% moisture content on dry basis for all feed rates. The minimum deseeding was noted at 25% moisture content on dry basis for all feed rates.

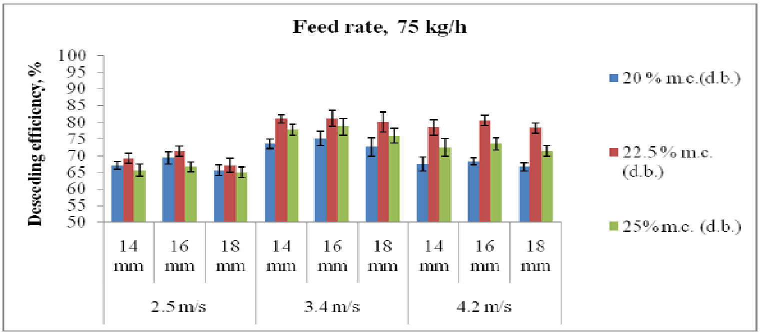

Figure 5. Effect of speed on deseeding efficiency at 75 kg·h^{-1} feed rates

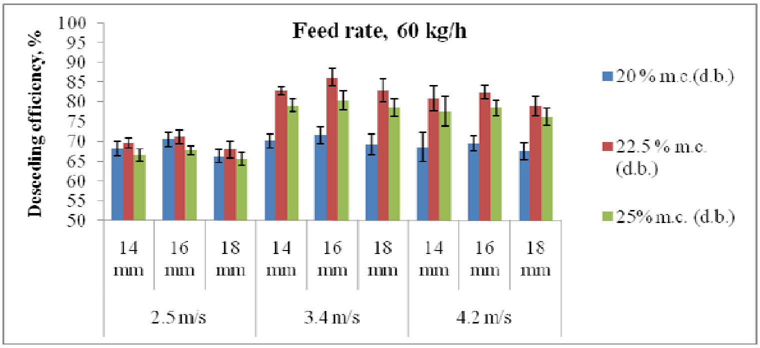

Figure 6. Effect of speed on deseeding efficiency at 60 kg·h^{-1} feed rates

It is also observed that the deseeding efficiency initially increased with increase in speed and then decreased, while the moisture content, feed rate and clearances were kept constant. The low deseeding efficiency at minimum speed was because of the low impact force applied on to the tamarind fruits which leads to partially shelled or unshelled condition of fruits at the outlet. Reduced efficiency at higher speed was due to shorter residence time of tamarind fruit in the deseeding unit. Among the three speeds, the maximum deseeding efficiency was obtained at 3.4 m·s^{-1} for all feed rates and the minimum deseeding efficiency was observed for the speed of 2.5 m·s^{-1} for all feed rates. Analogous results of increase in deseeding efficiency with increase in speed and then decrease with further increase in speed was observed for cashew nut shelling [7], water chestnut [8] and grain legumes [9].

It is also noted that the deseeding efficiency decreases with increase in feed rate at a given speed, moisture content and clearance. The lesser deseeding efficiency with higher feed rate was due to reduction in the residence time. High deseeding efficiency with lower feed rate was because of tamarind fruit has got enough time to be impacted. From Fig.7, among the three feed rates, the maximum deseeding efficiency was obtained at 45 kg/h with the peripheral speed of 3.4 $m \cdot s^{-1}$ and minimum deseeding efficiency at 75 $kg \cdot h^{-1}$ with the peripheral speed of 2.5 $m \cdot s^{-1}$. Results obtained in this study are on par with the results observed for bambara groundnut [10] sheanut [11] and mango stone [12].

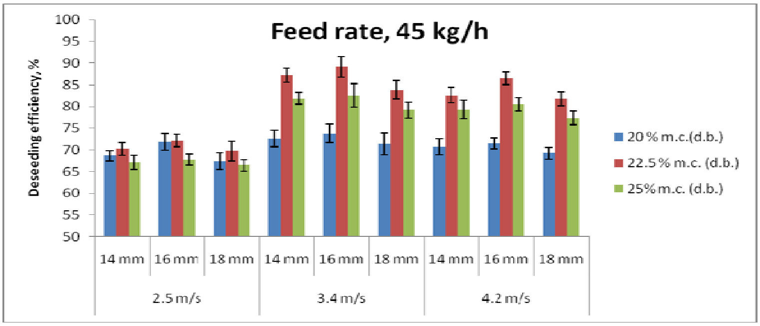

Figure 7. Effect of speed on deseeding efficiency at 45 $kg \cdot h^{-1}$ feed rates.

It can be also observed that the deseeding efficiency initially increased with an increase in clearance and then decreased when the moisture content and speed were kept constant. The lower deseeding efficiency at maximum clearance is attributed to less impact force applied on the tamarind fruits which leads to partially shelled or unshelled condition of fruits at the outlet. For the minimum clearance, more amounts of damaged fruit were noticed when compared to other two clearances. The results found were supported by the findings [13] for paddy threshing where the damage was found increasing with increasing impact load exerted by different materials on paddy and for wheat in case of thresher [14].

Analysis of variance (Tab. 2) shows that the effects of single factors namely moisture content, speed and feed rate were significant at 1 % level and clearance was significant at 5% level. Two factor interactions namely moisture content x speed, moisture content x feed rate and speed x feed rate were found to be significant at 5% level. Interactions namely moisture content x clearance, speed x clearance and clearance x feed rate were found to be non significant. Three factor interactions namely moisture content x speed x feed rate was found to be significant at 1 % level. Interactions namely speed x clearance x feed rate and moisture content x speed x clearance were significant at 5 % level and moisture content x clearance x feed rate was found to be non significant. Four factor interactions namely moisture content x speed x clearance x feed rate was also found to be non significant.

From the four factorial completely randomized block design, it was obtained that the treatment which includes the combination of wooden roller running at 3.4 $m \cdot s^{-1}$ with the feed rate 45 $kg \cdot h^{-1}$, irrespective of the moisture contents considered for the analysis was found to be the best among all the treatments tested. The combination of feed rate 45 kg/h with the wooden roller of 3.4 $m \cdot s^{-1}$ and clearance of 16 mm to deseed the tamarind at the moisture content of 22.5% on dry basis ($M_2S_2F_1C_2$) was considered as the best, since the maximum deseeding efficiency was obtained as 89.15%. Minimum deseeding efficiency (60.57%) was observed when the moisture content of feed is 25% on dry basis and speed, feed rate and clearance were 2.5 m·s^{-1}, 75 kg·h^{-1} and 18 mm, respectively.

Table 2. Analysis of variance for the efficiency of tamarind deseeder for various speed, moisture content, feed rate and clearance

Source of variation	*Degrees of freedom*	*Sum of squares*	*Mean squares*	*F-ratio*
Total	*80*	*18733.5545*	*77.4113*	*17.8941*
Treatment	*26*	*18041.3809*	*225.5170*	*52.1296***
Error	*54*	*692.1735*	*4.3261*	*1.00*
Moisture content (M)	*2*	*13297.8103*	*6648.9051*	*1536.9335***
Speed (S)	*2*	*3513.0000*	*1756.5000*	*406.025***
Feed rate (F)	*2*	*248.7212*	*124.3606*	*28.7467***
Clearance (C)	*2*	*470.1052*	*235.0526*	*54.3338**
M x S	*4*	*136.2021*	*34.0505*	*7.8710***
M x C	*4*	*57.6181*	*14.4045*	*3.3297 NS*
M x F	*4*	*195.4819*	*48.8704*	*11.2967***
S x C	*4*	*10.6223*	*2.6555*	*0.6139 NS*
S x F	*4*	*30.0587*	*7.5146*	*1.737***
C x F	*4*	*5.4895*	*1.3723*	*0.3172 NS*
M x S x C	*8*	*13.7160*	*1.7145*	*0.3963**
M x S x F	*8*	*30.1872*	*3.7734*	*0.8722***
M x C x F	*8*	*17.001*	*2.1250*	*0.4913NS*
S x C x F	*8*	*5.5414*	*0.6920*	*0.1601**
M x S x C x F	*16*	*9.8245*	*0.6140*	*0.1419 NS*

**Significant at 5 %level, ** Significant at 1 %level, NS non- significant*
SED: 0.00227 CD (0.05): 0.00450 CD (0.01): 0.00596

Cost Economics

The capacity of the developed tamarind deseeder was 45 kg·h^{-1} and the cost of operation of tamarind seed remover was \$0.019·kg^{-1}, whereas the conventional manual deseeding process, the cost was found to be \$ 0.07·kg^{-1} of tamarind fruit. The conventional method of deseeding is nearly 4 fold more expensive than mechanical deseeding. Mechanical deseeding saves 74.9 % of operation cost and 93.34% of operation time.

CONCLUSIONS

A tamarind deseeder was developed in this study. The performance evaluation of the deseeder showed that fruit moisture content, material feed rate and machine speed had significant effect on its performance indices.

The combination of feed rate 45 kg·h^{-1} with the wooden shaft of 3.4 m·s^{-1} and clearance of 16 mm to deseed the tamarind at the moisture content of 22.5% on dry basis was considered as the best among the eighty one different treatments tested in Agres package, since the maximum deseeding efficiency was obtained as 89.15%.

The deseeder has a compact design and a robust outlook. It will contribute to the enhancement of tamarind processing as it could be used to eliminate the tediousness of the present traditional methods of tamarind deseeding.

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RAZVOJ I ISPITIVANJE KONTINUIRANOG TIPA SEPARATORA SEMENA MAHUNARKI

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***Sažetak**:* Kontinuirani tip separatora semena iz mahuna kapaciteta 75 $kg \cdot h^{-1}$ konstruisan je i ispitivan u Institutu za inženjering prehrambenih i poljoprivrednih procesa Poljoprivrednog univerziteta Tamil Nadu, Coimbatore, India. Mašina se sastoji od separatorske jedinice i izlaza za izdvojeno seme i prazne mahune. U separatorskoj jedinici mahune su istovremeno izlagane silama udara i sečenja od klinova postavljenih na drveni valjak, koji lome i otvaraju mahune i istovremeno guraju seme napolje iz duguljastog sita. Posle izdvajanje semena, seme i prazne mahune se skupljaju odvojeno iz razdvojenih izlaznih otvora. Performanse razvijene mašine su ocenjivane na osnovu efikasnosti separacije. Pri ispitivanju su izvođeni ogledi u različitim uslovima rada, uključujući različite: vlažnosti plodova (20.0, 22.5 i 25.0%), brzine valjka (2.5, 3.4 i 4.2 $m \cdot s^{-1}$), protoke mase (45, 60 i 75 $kg \cdot h^{-1}$) i horizontalne zazore (14, 16 i 18 mm). Rezultati ogleda su pokazali da je mašina postigla maksimalnu efikasnost separacije od 89.15% pri: vlažnosti od 22.5%, brzini valjka od 3.4 $m \cdot s^{-1}$, protoku mase od 45 $kg \cdot h^{-1}$ i zazoru od 16 mm. U poređenju sa postojećim ručnim postupcima separacije, kontinuirani tip separatora postigao je skraćenje radnog vremena od 93.34% i smanjenje troškova rada od 74.9%.

***Ključne reči**: separator semena, separatorska jedinica, drveni valjak, efikasnost separacije*

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