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Design, development and performance evaluation of minor millet de-husker

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ABSTRACT

The study on the design and development of minor millet de-husker was done owing to the inability of existing millet de-huskers to meet the demand of tribal farmers. The existing millet de-huskers do not match the requirements such as size, capacity and price and are not popular in tribal hinterland. Keeping these points in mind a minor millet de-husker suitable for de-husking of kodo and little millet was designed with a capacity of 12 kg/h to meet out the requirements of the growers. It is composed of three basic units viz feeding unit, de-husking unit and discharge unit. The de-husking efficiency of minor millet de-husker was affected by moisture content of feed, feed rate, speed of rotating cone and the clearance between de-husking cones. The maximum de-husking efficiency for kodo millet was 48.5 and for little millet 52.0 per cent obtained at 167 and 150 rpm respectively at the feed rate of 12 kg/h. At the feed rate of 9 kg/h for kodo millet and 12 kg/h for little millet the maximum de-husking efficiencies were 48.74 and 52.21 per cent respectively. The de-husking efficiency was also affected by moisture content of feed and clearance between de-husking cones. At 12 per cent moisture content and 1.5 mm clearance the de-husking efficiency was maximum (50.0%) at the feed rate of 12 kg/h. From economic point of view the cost of processing per kilogram of feed was Rs 3.59.

Keywords: Minor millet de-husker; kodo millet; little millet; moisture content; de-husking efficiency

INTRODUCTION

Minor millets are small size cereal grains belonging to the family Poaceae (Gramineae). Millets are highly nutritious, non-glutinous and no acid-forming foods. Hence they are soothing and easy to digest. Minor millets are grown in almost every state of India under rainfed conditions. In Madhya Pradesh these are mainly grown in tribal districts which contribute to approximately 35 per cent of the total production of minor millets in India (http://mpkrishi.org/EngDocs/ Agritop/ Compendium/ chap3_firstpart.aspx#apysm). One of the barriers to increase millet processing in our country is non-availability of de-huskers specifically designed for the minor millets. Minor millets are very small in size and the husk on them is tightly attached with the endosperm therefore removal of husk is difficult during de-husking operation.

Traditionally de-husking of the kodo and kutki was carried out by using wooden mortar and pestle or by using locally available grinding stones. A woman could de-hull about 1.5 kg millets per hour by using a pestle and mortar. The product thus obtained was non-uniform with poor keeping quality. An indigenous mill named Jatta is also popular for de-husking of millets. It is made of a mixture of soil and straw that helps it to check deflocculating while working which is used by turning the upper plate. Milling time required used to be half day for 20-30 kg of minor millets with grain recovery of 40 ± 5 per cent (Pradhan et al 2010). All the traditional methods of de-hulling of minor millets are time consuming and labour intensive.

For the last 30 years efforts are being made to develop mid-capacity millet de-husking machines to reduce the drudgery of the growers/processors. Central Institute of Agricultural Engineering, Bhopal, Madhya Pradesh has developed a millet mill with a de-hulling capacity of 100 kg/h. Tamil Nadu Agriculture University, Coimbatore, Tamil Naud has also developed a millet de-huller with a de-hulling capacity of 100 kg/

h. Vivekanand Parvatiya Krishi Anusandhan, Almora, Uttarakhand developed a thresher cum pearler for minor millets. As these machines do not match the requirements (size, capacity and price) of the tribal farmers therefore they are not popular in tribal hinterland. A de-husker with small capacity and size may be suitable to meet out the requirements of millet grains.

MATERIAL and METHODS

Theoretical design and material selection: The prime function of de-husking unit is to detach the upper husk layers of the grains with minimum damage to grain kernel. Detachment of upper husk can be achieved by abrasion impact and frictional forces generated by the de-husking element of the machine. The abrasion forces in de-husker are generated by rotating an inner abrasive cone fitted inside a concentric fixed abrasive outer cone. Effectiveness of de-husking primarily depends on the moisture content of kernels, clearance between the abrasive surfaces, nature of abrasive surface, speed of rotation of the de-husking unit and feed rate.

Components of de-husker (Plate 1): De-husker consists of a frame of mild steel, angle iron and MS sheet. Other components such as feed hopper, de-husking unit and outlet are mounted on the frame. Power to de-husking unit is provided by an electric motor connected to the abrasive cone with the help of a belt and pulley arrangement.

Designing of machine components

Size of feed hopper: The size of the hopper was decided by the bulk density of the minor millets. A feed hopper of conical shape was selected.

Selection of electric motor: An electric motor of 1 hp power (P), 1725 rmp rational speed (N), 50 Hz frequency and single phase on the name plate was selected.

Selection of pulley: A cast iron pulley is fitted on the driving shaft. It is connected with the shaft of the frictional cone with the help of V-belt. The diameter of the pulley mounted on the shaft attached with the frictional cone can be calculated by using the formula:

$$N_1D_1 = N_2D_2 \quad .....1$$

where N_1= Rotational speed of an electric motor, D_1= Diameter of the motors pulley (3 in), N_2= Rotational speed of cone, D_2= Diameter of the pulley mounted on the shaft (9 in)

Design for belt

Selection of belt: Based on the power transmitted (kw) belt type A was selected from Table 1 (Khurmi and Gupta 2004).

Calculation of belt length (L): Khurmi and Gupta (2004) developed equation for calculation of belt length as shown below (Fig 1):

$$L = \pi/2\,(D_1 + D_2) + 2x + (D_1 + D_2)^2/4x \quad .....2$$

where L= Length of belt (in),D_1= Smaller sheave diameter= Dm (3 in), D_2= Larger sheave diameter= Dr (4 in), x= Centre distance of pulleys (in)

Design of shaft: A shaft is the rotating machine element which transmits power from one place to another (Khurmi and Gupta 2004). The shaft of the de-husker experiences the shear force only. The diameter of the shaft can be calculated by using Torsion equation as given below:

$$T= \frac{\pi}{16} \times r \times d^3 \quad .....3$$

where T= Twisting moment (Nm), d= Diameter of the shaft (m)= 1 in, τ= Torsional shear stress (N/m^2)

Number of belts required: The number of belts required to transmit kw power from electric motor was calculated using equation as suggested by Khurmi and Gupta (2004):

$$n = \text{Motor power/Power per belt} \quad .....4$$

Selection of bearing: Ball rolling contact bearing of standard designation 307 was selected for minor millet de-husker. This selection was based on the type of load the bearing would support when at rest and during operation and on the diameter of the shaft. The designation 307 signifies medium size bearing with bore (inside diameter) of 35 mm (Khurmi and Gupta 2004)

Selection of the abrasive material attached at the rotating cone: A steel wire mesh was attached to the inner surface of the cone fixed with the frame of the machine and at the outer surface of the rotating cone.

Height of the machine: The machine was designed for the persons having average height ranging from 5 to 6 feet (Deaton 2008). The height of the machine was decided from the ergonomic point of view. Height of the machine was 4.2 feet.

Experimental plan: To evaluate the efficiency and capacity of the millet de-husker experiments were conducted using the experimental plan (Table 2).

Measuring parameters

Grain parameters: Moisture content (%, wb), size (mm), geometrical mean diameter (mm), bulk density (kg/m^3), angle of repose Φ (^{o})

Machine parameters: De-husking efficiency (%), capacity (kg/h)

RESULTS and DISCUSSION

Calculating de-husking efficiency: De-husking efficiency was calculated by following expression:

Shelling/de-husking (%)= [1- (Weight of unhusked grains/ Weight of total grains after de-husking)] × E_{wk} × 100

where Coefficient of wholeness (E_{wk})= Weight of whole kernels/Weight of whole kernels + Weight of brokens kernels

Testing of minor millet de-husker: To test the machine raw kodo and little millet were procured from local market. The de-husking unit was tested for running it continuously for an hour. De-husking performance for kodo and little millet was checked separately. After

Table 1. Dimensions of standard V-belts

Type of belt	Power range (kw)	Minimum pitch diameter (D) of pulley (mm)	Top width (b) (mm)	Thickness (t) (mm)
A	0.7-3.7	75	13	18
B	2-15	125	17	11
C	7.5-75	200	22	14
D	20-150	355	32	19
E	30-350	500	38	23

Table 2. Experimental plan for evaluating de-husking efficiency and capacity of the machine

Variable	Level	Value
Speed of the abrasive cone (rpm)	11	33 to 200
Roller concave clearance (mm)	3	1, 1.5, 2
Feed rate (kg/h)	3	9, 12, 15
Moisture content of feed (%,wb)	3	11, 12, 13

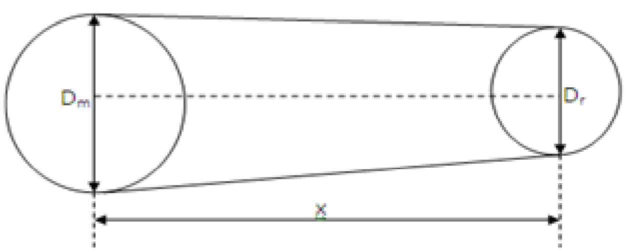

Fig 1. Open belt drive

Plate 1. Developed minor millet de-husker

de-husking, de-husked grains were collected through discharge chute and weighed to find out de-husking efficiency. De-husking efficiencies of kodo and little millet were calculated.

Performance evaluation of the de-husking unit

Effect of de-husking cone speed on de-husking efficiency: The rpm selected for de-husking of kodo millet ranged from 33 to 200. Clearance between the de-husking cone and outer fixed cone was kept 1.00 mm and at a certain feed rate of 12 kg/h. Initially de-husking efficiency increased with increase in the rotational speed of de-husking cone and after a certain value of speed of cone (167 rpm) it started reducing.

The de-husking efficiency increased from 20.0 per cent to a maximum value of 48.5 per cent when the rotational speed of de-husking cone was increased from 33 to 167 rpm. The de-husking efficiency started reducing when the speed of de-husking cone increased beyond 167 rpm (Fig 2).

The rpm selected for de-husking of kodo millet ranged from 33 to 200. Data obtained indicate that the de-husking efficiency was affected by the speed of rotation of the de-husking cone for a given clearance (1 mm) and feed rate (12 kg/h). Initially de-husking efficiency increased with increase in the rotational speed of de-husking cone and after a certain value of speed of cone (150 rpm) it started reducing. The de-husking efficiency increased from 29.7 per cent to a maximum value of 52.0 per cent when the rotational speed of de-husking cone increased from 33 to 150 rpm. The de-husking efficiency started reducing when the speed of de-husking cone increased beyond 150 rpm (Fig 3).

The de-husking efficiency of the minor millet de-husker depends upon the moisture content of the feed, clearance between rotational and stationary cones and speed of rotation of de-husking cone at a given feed rate.

Effect of moisture content, clearance and de-husking cone speed on de-husking efficiency of minor millet de-husker: De-husking efficiency increased with increase in rpm of de-husking cone for given clearance and moisture content of the grains (Fig 4). At 11 per cent moisture content (wb) and 2 mm clearance between the rotational and stationary cones the de-husking efficiency increased from 33.88 to 36.67 per cent when the speed of rotation of de-husking cone increased from 150 to 200 rpm. Similarly the de-husking efficiency increased from 44.77 to 49.19 per cent when the speed of rotation of de-husking cone increased from 150 to 200 rpm at 1.5 mm clearance and moisture content of kodo millet at 12 per cent (wb). And also at 13 per cent moisture content (wb) the de-husking efficiency increased from 38.73 to 45.29 per cent when the de-husking cone speed increased from 150 to 200 rpm at 1 mm clearance.

Maximumde-husking efficiency (49.19%) was obtained at 12 per cent moisture content (wb) of kodo millet, 1.5 mm clearance and the 200 rpm of de-husking cone.

The de-husking efficiency for little millet was also observed at four selected de-husking cone speeds and clearances when the feed rate was constant ie 12 kg/h. It was observed that de-husking efficiency was maximum (50.23%) at 12 per cent (wb) moisture content and 1.5 mm clearance (Fig 5). The minimum de-husking efficiency was observed 31.09 per cent at moisture content 11 per cent (wb) and clearance 2 mm. The decrease in de-husking efficiency with decrease in moisture content and increase in clearance was mainly due to direct losses.

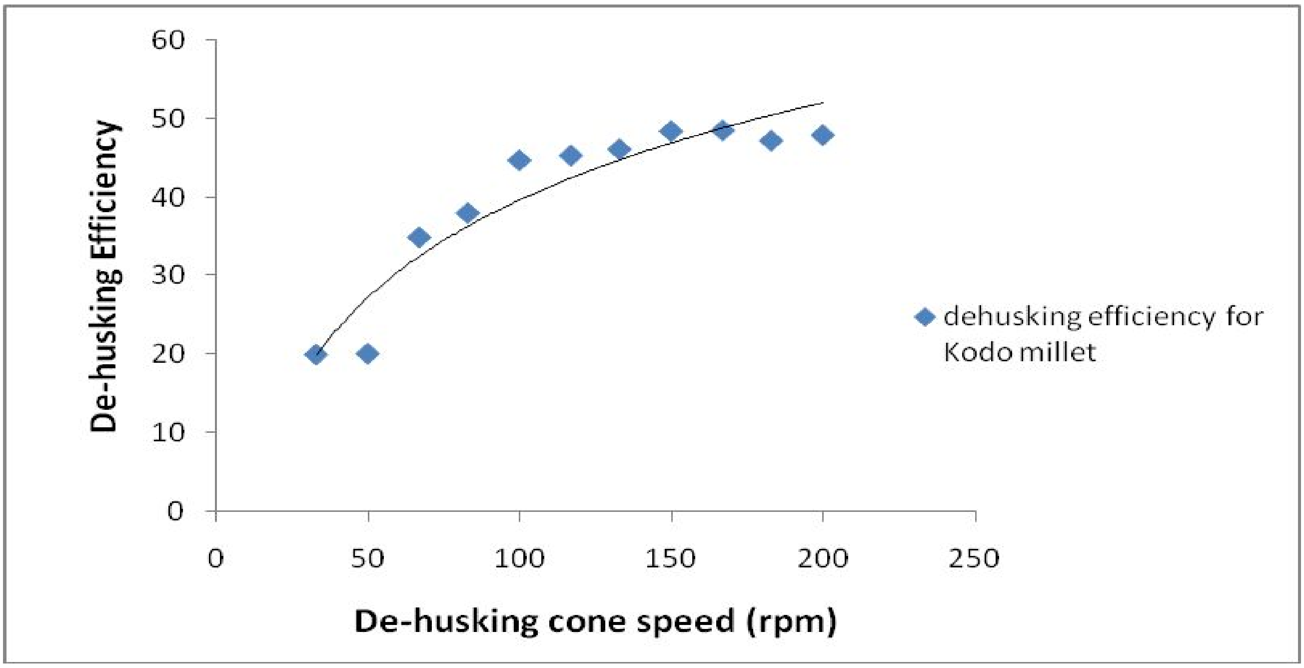

Fig 2. Effect of de-husking cone's speed on de-husking efficiency (for kodo millet) of minor millet de-husker

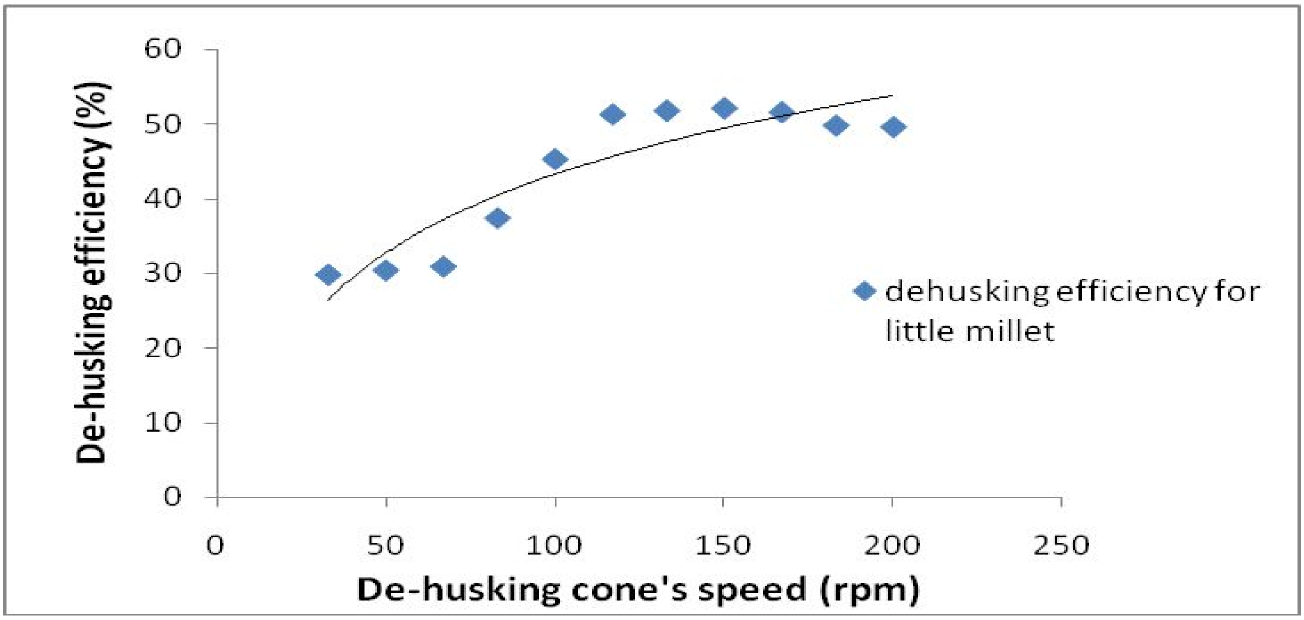

Fig 3. Effect of de-husking cone speed on de-husking efficiency (for little millet) of minor millet de-husker

Effect of feed rate on de-husking efficiency (for kodo millet): To determine the effect of feed rate on de-husking efficiency three samples of kodo millet were selected and de-husked at three de-husking cone speeds viz 150, 167 and 183 rpm. The de-husking efficiency was maximum (48.74%) at 9 kg/h feed rate at de-husking cone speed of 150 rpm (Fig 6). The minimum value of de-husking efficiency (37.38%) was observed at feed rate of 15 kg/h at de-husking cone speed of 150 rpm. The de-husking efficiency decreased with increase in feed rate because of higher amount of feed leading to difficult twisting action.

To determine the effect of feed rate on de-husking efficiency three samples of little millet were selected and de-husked at three de-husking cone speeds viz 133, 150 and 167 rpm. From the Fig 7 it is clear that the de-husking efficiency

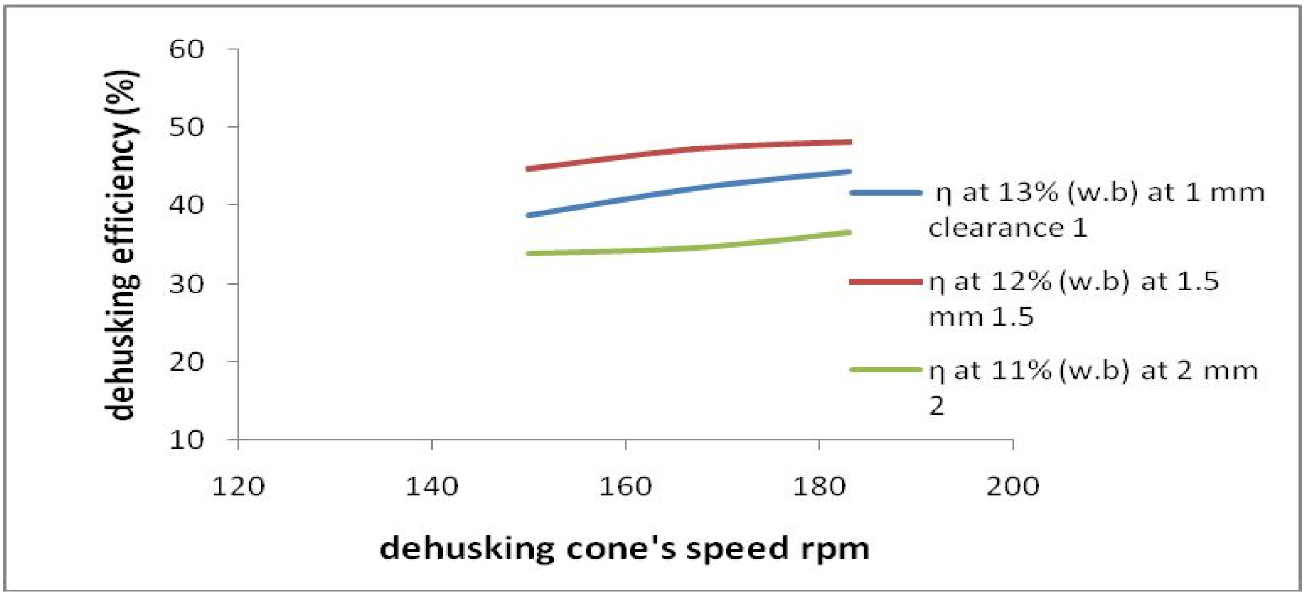

Fig 4. Effect of moisture content of kodo millet on de-husking efficiency of minor millet de-husker

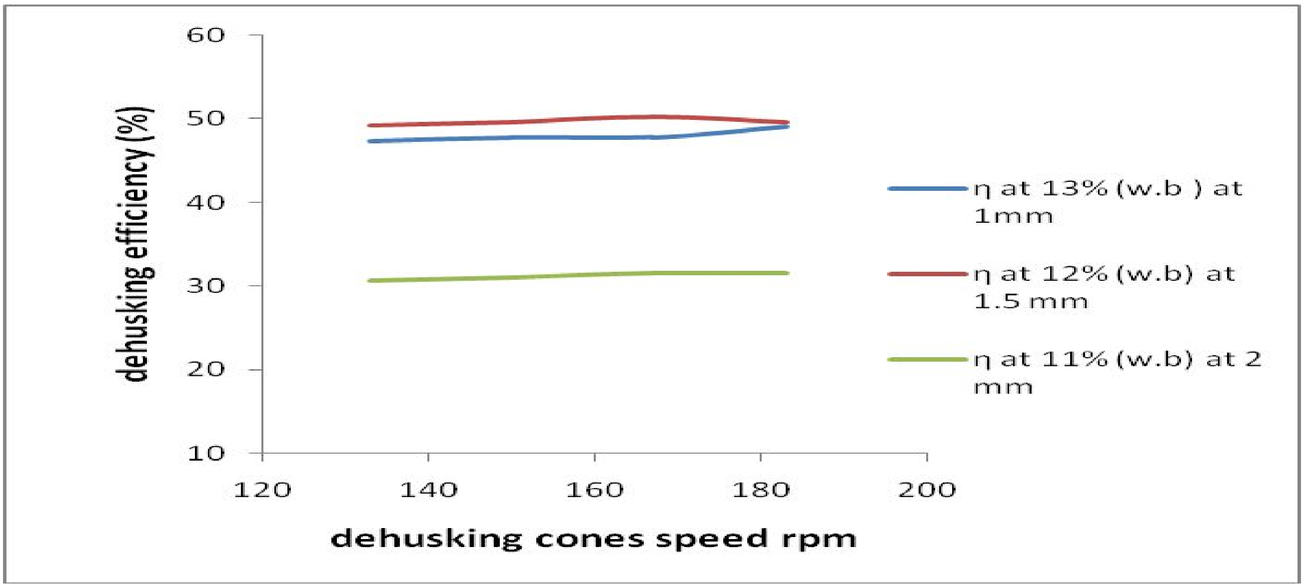

Fig 5. Effect of moisture content of little millet on de-husking efficiency of minor millet de-husker

was maximum (52.21%) at 12 kg/h feed rate at de-husking cone speed of 167 rpm. The minimum de-husking efficiency (41.31%) was observed at feed rate of 15 kg/h at de-husking cone speed of 133 rpm. The de-husking efficiency decreased with increase in feed rate as higher amount of feed lead to difficult twisting as well as rubbing action.

CONCLUSION

The de-husking efficiency of minor millet de-husker was affected by the speed of rotating cone, feed rate, moisture content of feed and the clearance between de-husking cones. The maximum de-husking efficiency for kodo millet was 48.5 per cent and for little millet 52.0 per cent obtained at 167 and 150 rpm respectively at the feed rate of 12 kg/ h. At the feed rate of 9 kg/h for kodo millet and 12 kg/h for little millet the maximum de-husking efficiencies were 48.74 and 52.21 per cent respectively. The de-husking efficiency was also affected by moisture content of feed and clearance between de-husking cones. At 12 per cent moisture content and 1.5 mm clearance the de-husking

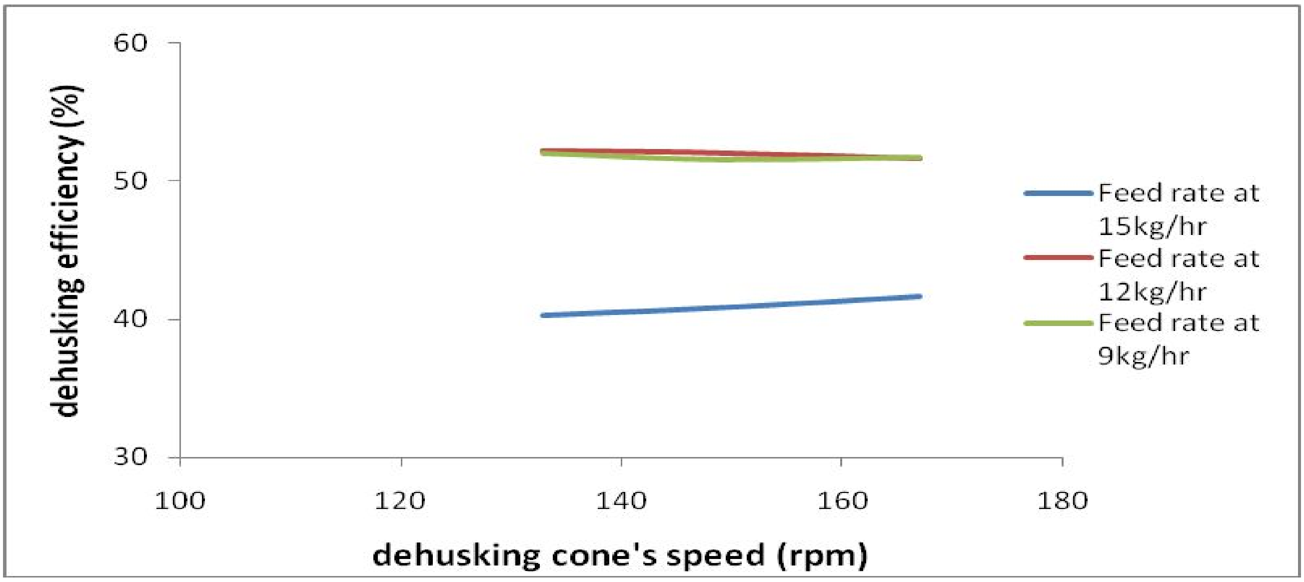

Fig 6. Effect of feed rate on de-husking efficiency of minor millet de-husker (for little millet)

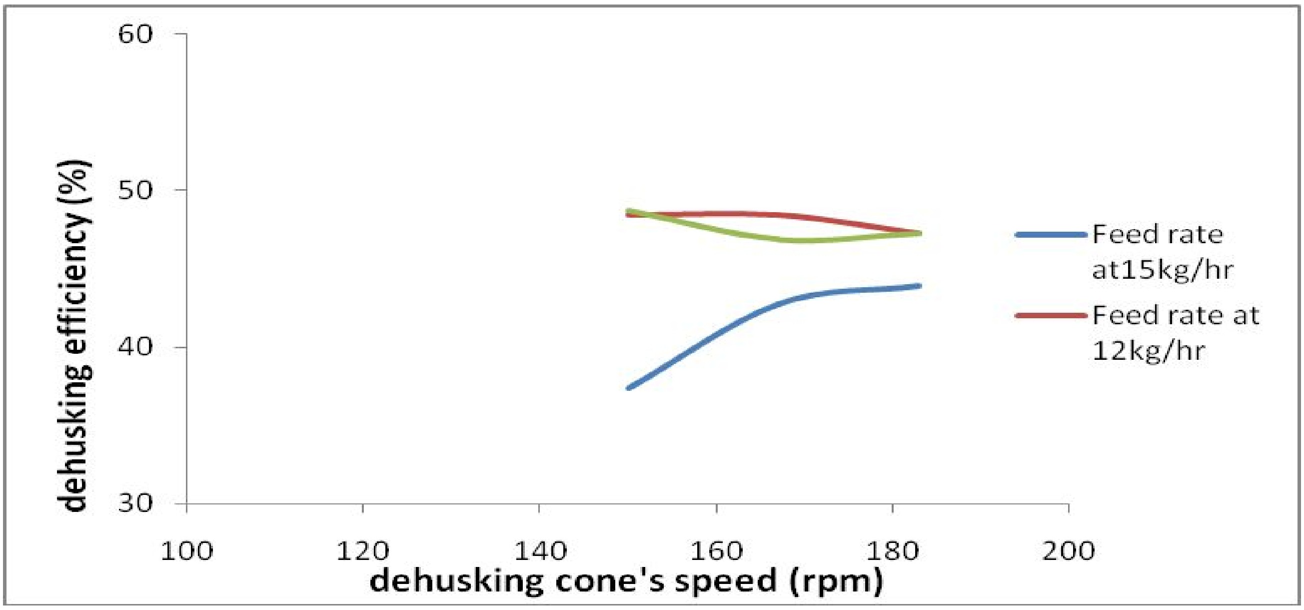

Fig 7. Effect of feed rate on de-husking efficiency of minor millet de-husker (for kodo millet)

efficiency was maximum (50.0%) at the feed rate of 12 kg/h.

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