Research Article

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Design and development of dehusker suitable for fresh arecanut

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Abstract

Arecanut is primarily cultivated for obtaining kernel from its fruit which is chewed in the tender, ripe or processed from. Manual dehusking of arecanut is a slow and tedious process and needs skilled labour. Frequently, due to lack of skilled labour all the fresh areca nuts could not be dehusked immediately. Hence to overcome this problem, farmers are in need of a dehusker for freshly harvested arecanut. Hence, development of suitable unit for dehusking fresh arecanut was contemplated. The physical and mechanical properties of green arecanut and kernel as well as husk were studied. Similarly the effect of compression on the failure of husk and kernel was studied. The husk failed at 0.28 kN of axial loading and the husk and nut failed at 0.36 kN of radial loading. A prototype model which can be operated either manually or by 1.5 kW electric motor was developed with two different types of blades *i.e.*, saw tooth circumferential blades and longitudinal profiled blades. By manual operation the dehusking efficiency were 42 per cent and 63 per cent, respectively for saw tooth and profiled tooth drums. When the dehusker was operated by electric motor the performance was satisfactory with profiled tooth drum. The dehusking efficiency was 82 per cent, damage to kernel was 18 per cent and the capacity was 48 kg of kernel per hour.

Keywords: Arecanut, blade, dehusker, efficiency, performance

Introduction

India ranks first in terms of both area (47%) and production (47%) of arecanut. The other countries which produce arecanut in the world are Bangladesh, China and Indonesia. The world productivity of arecanut stood at 1.21 t ha^{-1}. Indian productivity is also on par with the world productivity (1.27 t ha^{-1}). Arecanut is grown in around 4,00,000 hectares and production is estimated at 477,000 tonnes during 2012-13 (Ramappa and Manjunatha, 2013). In India, production is concentrated in six states, namely Karnataka, Kerala, Assam, Meghalaya, Tamil Nadu and West Bengal. The ever increasing demand for areca products like paan, supari and gutkha has led to continuous increase in arecanut prices worldwide. The processing methods, maturity and consumer preferences influence the types of arecanut products prepared (Anand *et al.,* 2012).

Usually the fresh arecanut harvested is dehusked within 24 hours. Manual dehusking of arecanut is slow process and needs skilled labour. Frequently due to lack of skilled labour all the fresh arecanuts cannot be dehusked immediately. Some efforts are have been made in the past to develop dehusking unit for dry arecanut.

Wang (1963) proposed a mathematical model for designing of a frictional roller poha-berry husking machine. The model not only indicated that both friction and normal forces caused the husking of the berry but also provided an estimate of roller size.

Baboo (1981) developed a device for dehusking dry arecanut fruit. The device comprised a scissor mechanism, a frame, a platform and a pedal operated lever mechanism. The device, which was operated by two workers, could dehusk 13.4 kg of arecanut in 1 h.

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A power operated dehusker for dried arecanut fruits was developed at the Department of Agricultural Processing, TNAU, Coimbatore (Anonymous, 1981). The dehusker consisted of a mainframe on which a rotary shelling drum like rasp bar threshing cylinder having 8 solid rubbers mounted on its periphery. A concave was placed below the shelling drum to aid shelling and to pass the dehusked material down. After dehusking kernels, the husk flow to the duct and reach the air stream, produced by a blower. The husk was thrown out and the kernels/nuts were collected at the bottom. The capacity of the unit was 30 kg h^{-1}.

The mechanical properties of the arecanut in relation to dehusking were studied by Balasubramanian and Panwar (1986). It was reported that lateral shear with a rubbing action might be suitable for dehusking the fruit. It was also noted that the moisture content of the dry fruit should be in the range of 5 to 6 per cent of weight basis for the technique to be most efficiently used.

Varghese and Jacob (1998) developed a power-operated arecanut dehusker. The major parts of the dehusker were hopper, feeder, lead plate, cutting blade, shearing roller, friction plate and scraper. The feeder received the dried and graded nut from the hopper and delivered it on the lead plate. The nut was compressed between the rotating shearing roller and the lead plate. The teeth on the roller peeled off the husk and the kernel was ejected through the slot on the lead plate and the husk was removed. The dehusker was powered by single phase 0.5 hp motor with an output of 9.0 kg dried nut h^{-1} for a single unit and 84.5 per cent dehusking efficiency.

Jarimopas and Niamhom (2004) developed a dry betel nut shelling machine. The husking mechanism featured one 10-5.00 tyre and a sieve, constructed from steel rods, which was curved under the tyre. The design concept of the shelling machine was similar to the idea proposed by Wang (1963) in which the husking was exerted by both friction and normal forces although a point of difference was that husking did not occur between two rollers but through the use of a single rotating tyre and a stationary sieve. However, the sieve, which was supported by a spring proved to be rather inefficient because it often came loose, causing a high degree of incomplete husking.

Niamhom *et al.* (2007) introduced a new design for a betel nut fruit husking machine. Its husking mechanism comprised two commercial 10-5.00 rubber tyres hinged adjacent to and parallel with a concave sieve. The tyres were inflated to a pressure of 138 kPa and rotated at 448 rpm. However, the it was difficult to operate the equipment at the optimized parameters.

Jarimopas *et al.* (2009) designed and evaluated dry betel nut husking machine The design concept was to tear-off the husk of the dry betel nut by exerting differing dynamic friction forces on opposite sides of the nut via normal pressure. The prototype featured a hopper into which dry betel nuts were fed, a husking mechanism, and a power drive. The husking mechanism was composed of two identical husking wheels mounted in series. Each husking wheel consisted of a rubber tyre and a concave sieve constructed from steel rods. The dry betel nut was fed into the space between the running tyre surface and the sieve surface of the husking mechanism. When the nut passed through the first wheel, the combined compression and friction force crushed the nut husk and loosened the nut. The husk and nut were further separated by repeating the operation with a second tyre.) Optimum machine settings was obtained at a tyre pressure of 138 kPa, a tyre speed of 440 rpm, and a 15 mm spacing between the surfaces of the tyre and the sieve. The optimal betel nut fruit moisture content was 6.31 per cent w.b. At the optimum setting, the dehusking efficiency obtained was 64.4 per cent with broken nuts at 15.2 per cent and unhusked nuts at 20.5 per cent.

However, these machines could not be adopted for dehusking fresh arecanut. Hence, development of suitable unit for dehusking fresh areca nut was contemplated which would reduce the time involved, labour requirement and cost of dehusking.

Materials and methods

Physical and mechanical properties of arecanut

To design the various components of dehusking mechanism, the physical properties like dimension of fruit, husk thickness, weight, volume, density as well as the mechanical properties like lateral and axial compression required to break open the husk at different moisture content of arecanut were studied. The physical properties are given in Table 1.

Table 1. Physical properties of arecanut

Sl. No.	Physical parameter	Range	Mean Value
1	Axial dimension of fruit		
	i. Length (mm)	42.3 – 65.4	52.6
	ii. Diameter (mm)	26.7 – 45.4	33.1
2	Axial dimension of kernel		
	i. Length (mm)	21.8 – 32.4	26.3
	ii. Diameter (mm)	19.7 – 28.2	21.6
3	Thickness of husk		
	i. Side lateral (mm)	4.2 – 5.2	4.5
	ii. Top axial (mm)	12.4 – 17.6	14.6
4	Weight		
	i. Fruit (g)	36.0 – 61.0	48
	ii. Kernel (g)	18.4 – 22.1	19.4
	iii. Husk (g)	16.0 – 41.2	28
5	Density		
	i. Fruit (g cm^{-3})	0.62 – 0.74	0.67
	ii. Kernel (g cm^{-3})	1.31 – 1.34	1.32

The arecanut fruit was subjected to compression stress in universal testing machine. Load v/s deformation curve was plotted at different moisture content. The pattern of failure of husk was also studied with reference to two different orientations of the fruit. The study was taken up in line with the earlier studies carried out by Aviara *et al*. (2012) for *Mucuna flagellipes* nut and Bart *et al*. (2012) for cocoa beans. The failure pattern of the husk is show in Fig. 1.

In case of axial compression of fresh arecanut, husk splits into 5 to 6 pieces axially along its length.

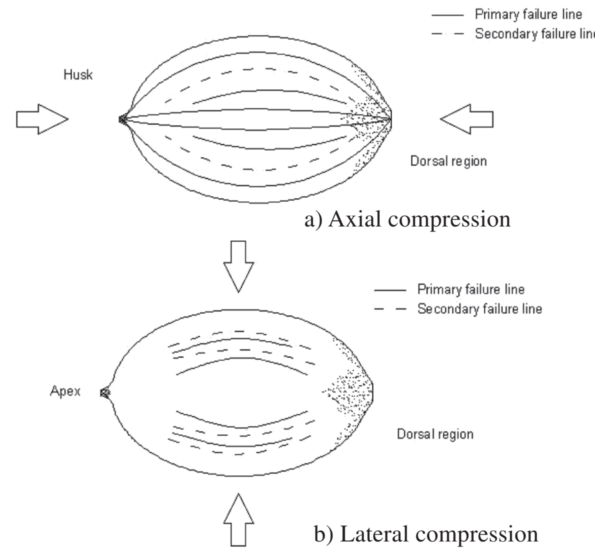


Fig.1. Failure pattern of arecanut husk in compression

The failure load and displacement pattern of husk and nut were distinct. However, in radial compression, husk and nut deformed simultaneously without distinct failure of husk and nut. The compression load and deformation during the failure of husk and nut were recorded and average value of load and deformation for husk and nut during failure are given in Table 2.

Development of arecanut dehusker

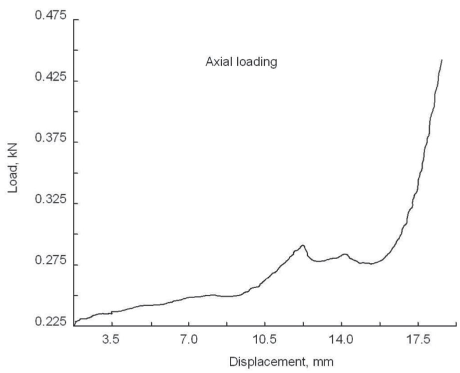
Based on the physical and mechanical properties, a simple device to dehusk fresh arecanut was conceptualized with a dehusking drum and spring loaded concave, as shown in Fig. 3. The important part of dehusker are electric motor, clutch, serrated blades, reciprocating drum, feed hopper, adjustable jaw, outlet, speed reduction gear box and outlet frame.

Dehusking drum with saw tooth circumferential blade

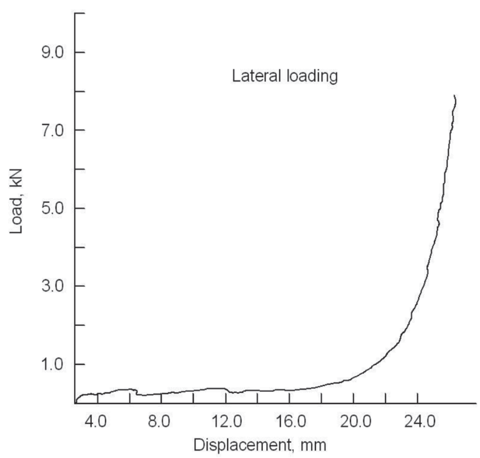
The drum is having a diameter of 31.6 cm and 7 cm width. The outer surface of the drum is fixed

Table 2. Compression load and deformation of arecanut

Sl. No.	Type of loading	Moisture % content, (wb)	Failure of husk		Nut	
			Deformation (mm)	Load (kN)	Deformation (mm)	Load (kN)
1.	Axial	54-62	4.0	0.28	7.4	37.5
2.	Radial	54-62	3.2	0.36	-	-



a. Lateral loading



b.Radial loading

Fig. 2. The load v/s deformation curve for both lateral and radial loading for fresh arecanut is show in figure 2a and b.

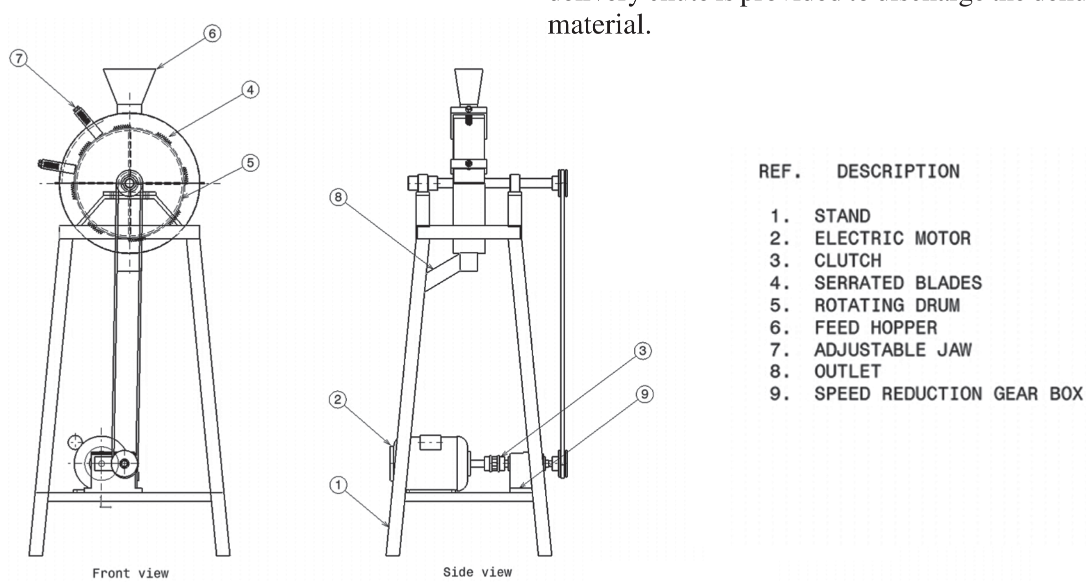


Fig. 3. Arecanut dehusker

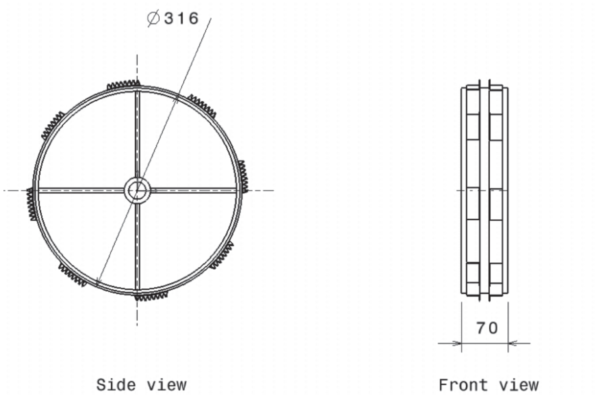
with saw tooth blades of 48 mm length, 8 mm height and 6 mm tooth pitch. The blades are fixed intermittently in parallel manner as shown in Fig. 4.

Dehusking drum with longitudinal profiled blade

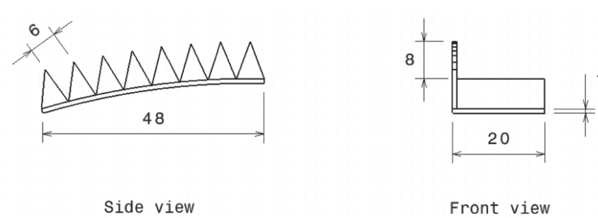
In this drum, longitudinal profiled blades (Fig. 5) were mounted on the periphery of the drum. The blades are fixed parallel to the drum axis. The blade is designed to cut into the husk and the nut while the husk is sheared by action against the concave. The length of blade is 70 mm and height is 27 mm with 5 mm clearance at both sides of drum. The blade with 4 pointed tooth pierce in to the fruit at two edge of the fruit and remove the husk due to twisting action. The spacing between blades is 12 mm, hence during rotation the blade splits the husk into 6 or 7 pieces. The centre portion of the blade is having a curved profile to prevent damage to the nut. The height of inner pair of teeth is 10 mm and the outer pair is 13.5 mm to accommodate the fruits of different lengths.

Inlet and outlet openings

The concave is provided with a small hopper at the top with an opening of 80 mm x 50 mm to feed the arecanut one by one. The kernel and husk are collected at the bottom of the concave. For easy exit of husk and kernel, an opening of 130 cm x 85 cm is provided at the bottom of the concave. A delivery chute is provided to discharge the dehusked material.



Rotating Drum



Serrated Blade

Fig. 4. Dehusking drum with saw tooth circumferential blade

Spring loaded concave

The concave is specially designed to perform two functions. It gently presses the arecanut, against the rotating drum. Which automatically varies the clearance to suit different sizes of arecanut. The spring loaded section of concave is 200 mm x 80 mm. It is provided with spring at both ends to press the nut against the dehusking drum. The inner surface of the concave is lined with hard rubber lining of 10 mm thickness.

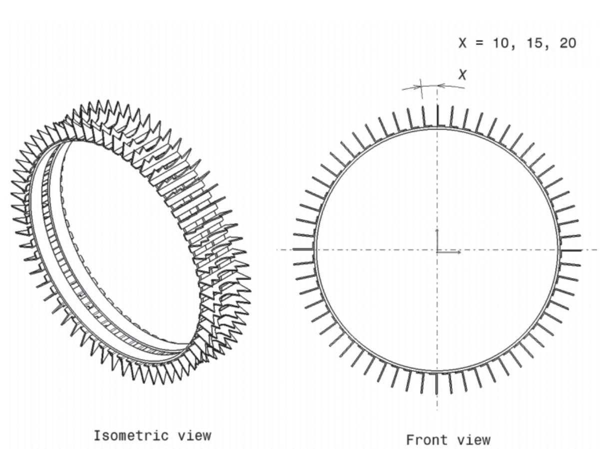


Fig. 5. Dehusking drum with longitudinal profiled blade

Power source

The dehusker can be operated either manually or using power. During manual operation the drum is cranked by a handle. For powered operation, a 1.5 kW three phase motor is used. Power is transmitted through suitable V-belt and pulley with reduction of 5:1. To vary the speed of electric motor for experimental purpose, an electronic variable speed drive was used.

Main frame

The main frame is made of 40 mm mild steel angle with dimension of 570 mm x 460 mm x 950 mm. The dehusking drum assembly is mounted on the frame on two pedestal bearing units.

The different type of dehusker rotors tried during experimentation is given in Fig. 6.

Results and discussion

The arecanut dehusker developed was tested to evaluate its performance in terms of dehusking efficiency, breakage of kernel and output. The unit was operated manually as well as using power.

Performance of manually operated dehusker

The arecanut dehusker was operated by manual cranking of dehusking drum fitted with saw tooth circumferential and longitudinal profiled tooth blades for fresh arecanuts. The moisture content of husk and physical dimension of fruit were recorded. The arecanut was fed one by one at regular internal and the drum was rotated at speeds ranging from 40-100 rpm. The performance data recorded are given in Table 3.

During manual rotation of drum in both saw tooth and profiled tooth the operating speeds of drum could not be maintained at specified speed. The saw tooth drum was operated at an average drum speed of 50 rpm during dehusking. The damage noticed was 10 per cent with a dehusking efficiency of 42 per cent. In profiled tooth drum dehusking efficiency of 63 per cent was observed at an average drum speed of 70 rpm. The damage to kernel was 8 per cent.

Fig. 6. Arecanut dehusker with different types of dehusking rotors

Performance of power operated dehusker

To enhance the capacity and also to reduce the labour requirement the dehusker was fitted with 1.5 kW electric motor and the dehusking efficiency, breakage of kernel and capacity were recorded. The consolidated data for dehusking by both drums is given in Table 4.

The dehusking mechanism was tested at different speeds and the optimum speed was arrived for each model. For saw tooth drum at optimum drum speed of 140 rpm the dehusking efficiency was observed as 34 per cent with a kernel damage of 16 per cent and the capacity was 22 kg h^{-1}. In longitudinal profiled tooth drum it was operated at a higher speed of 260 rpm and the dehusking efficiency was recorded as 82 per cent with 18 per cent kernel damage and capacity of 48 kg of kernel per hour.

Conclusion

The physical and mechanical properties like axial dimension of green arecanut and kernel as well as husk thickness were studied. Similarly the effect of compression on the failure of husk and kernel was studied. The husk failed at 0.28 KN of axial loading and the husk and nut failed at 0.36 KN of

Table 3. Performance of manually operated dehusker

Sl. No.	Parameters	Data recorded: Saw tooth blade	Data recorded: Profiled toothblade
1	Moisture content of husk (% wb)	56	56
2	Size of arecanut		
	Length (mm)	56-65	56-65
	Diameter (mm)	42-46	30-46
3	Size of kernal		
	Length (mm)	29-32	29-32
	Diameter (mm)	26-29	26-29
4	Drum speed (rpm)	50	70
5	Dehusking efficiency (%)	42	63
6	Damage to kernel (%)	10	8
7	Capacity-kernel (kg h^{-1})	14	18

Table 4. Performance of dehusker operated by electric motor

Sl. No.	Parameters	Data recorded: Saw tooth blade	Data recorded: Profiled tooth blade
1	Moisture content of husk (% wb)	58	58
2	Size of arecanut		
	Length (mm)	54-60	54-60
	Diameter (mm)	40-42	40-42
3	Optimum speed of drum (rpm)	140	260
4	Dehusking efficiency (%)	34	82
5	Damage to Kernel (%)	16	18
6	Capacity (kg h^{-1})	22	48

radial loading. A prototype model was developed, which can be operated either manually or by 1.5 kW electric motor. By manual operation the dehusking efficiency were 42 per cent and 63 per cent, respectively for saw tooth and profiled tooth drums. When the dehusker was operated by electric motor the performance was satisfactory with profiled tooth drum. The dehusking efficiency was 82 per cent, damage to kernel was 18 per cent and the capacity was 48 kg of kernel per hour. This equipment has immense scope in small and medium arecanut processing industries.

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