

SOME ENGINEERING PROPERTIES OF ARECANUT HUSK (*Areca catechu* L.) USEFUL IN WASTE TO WEALTH CONVERSION

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Abstract

Engineering properties are important in efficient use of biomass like arecanut husk, in the conversion from waste to useful industrial and economically important products. Arecanut husk has many uses like raw material for production of industrial chemicals (ethanol, xylose, furfural), enzyme, mushroom and it's fibre for making of composites, fabrics, thick boards, fluffy cushions, non-wovens, paperboards, thermal insulators. These usage from arecanut husk needs the characterisation from process point of view. In present study some of the important engineering properties of arecanut husk cv Shreevardhinin in dry as well as water soaked conditions were determined. Dry arecanut husk (MC 12.10 per cent w.b.) had average values in respect of length, width, thickness, bulk density, true density and angle of repose of 55.52 mm, 47.04 mm, 3.01 mm, 99.63 kg/m³, 444.97 kg/m³, and 36.20°, respectively. The fibre content, tear force, and impact energy required to separate fibre from husk was found to be 80.20 per cent, 62.70 N, and 13.32 kg/m, respectively. Water soaking increased the mean values of bulk density to 310.73 kg/m³, and angle of repose to 38.13°. But impact energy required to separate fibre from husk was reduced to 2.2 kg-m.

Key words: arecanut, husk, properties, size, density, angle of repose, soaked, fibre content, impact energy

Introduction

More than 76 species in genus arecaeae from palmae family are reported in the world. Arecanut is grown in Asia, Australia and Africa continents. Although being exotic in nature to India, arecanut is widely grown in North Eastern hilly part as well as peninsular Indian region. In 2013-14, India, being largest producer, produced 7,29,810 t arecanut from an estimated area of 4,45,000 ha with an average yield of 1,640 kg/ha, the statistic is an all-time high (Anonymous, 2015). India contributed about 50 per cent of the world production of arecanut, which was 12,24,125 t in 2012-13. Arecanut is cultivated in 14 Indian states and union territories. Karnataka, Kerala and Assam are the major producers of arecanut. Arecanut is mainly used for making supari (masticator) and allied products in world in general and India in particular. In spite of being famed for its notoriety of carcinogenetic, arecanut is used from ancient times in religious and social ceremonies. Owing its useful constituents, arecanut kernel has many uses, as reported previously.

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The fully dried arecanut fruit contains 40 per cent husk and 60 per cent kernel by weight. Arecanut husk is a solid biomass generated as waste after kernel removal from fruit. Taking into consideration the arecanut production (7,29,810t) of India in 2013-14 and 40 per cent husk generation, it is estimated that 2,91,924 t of dried husk was available in India which is huge quantity of agricultural biomass. The husk is now being largely wasted except for being used as an inferior fuel in households as well as in processing units.

Many researchers have carried out studies to efficiently convert this waste biomass into wealth. Singh (1956) obtained 5.5 per cent furfural from arecanut fruit husk by an acid catalysed high temperature and high pressure process. Kapadi et al. (1982) processed the arecanut husk for recovery of xylose and high quality activated charcoal. The study yielded 9 to 11 per cent crude xylose, 2 to 3 per cent pure xylose, and 25-28 per cent crude charcoal. Rajan et al. (2005) conducted studies to produce enzyme manganese peroxidase (MnP) from arecanut husk fibre (cv. Mangala) using basidiomycetes (*Phanerochaete chrysosporium* and *Phanerochaete* sp.). It was found that maximum MnP production of 233.2 IU ml⁻¹ was observed at pH 7 for *P.chrysosporium*. Prasad et al. (2007) recorded that arecanut husk was a potential renewable biomass resource for ethanol production. Rathod (2011) found arecanut husk as a good fuel for developed burning chamber. Chanakya and Malayil (2011) tried sustainable disposal of arecanut husk using plug flow type biogas. The resultant products were biogas (45 per cent), fibre (50 per cent) and compost (5 per cent). Narayanamurthy et al. (2012) investigated the

feasibility of citric acid production from areca husk under solid state fermentation and optimized physico-chemical parameters for obtaining maximum citric acid production.

The fibre could be used for making thick boards, fluffy cushions and non-woven fabrics (Ghosh et al., 1975). Ashok Kumar et al. (2011) reported that betel nut fruit could produce nearly 2.55 - 2.70 g of fibre which was utilised in manufacture of non-woven fabrics. The fabric possessed excellent dyeing behaviour and was virtually excellent substitute for conventional synthetic nets, with good drape, strength permeability, and resistance to sunlight, heavy rains, and hailstorm for long periods. Yusriah et al. (2012) and many earlier researchers stated that arecanut husk could be employed as reinforcement in fabricating natural fibre reinforced polymer composites which were fully biodegradable, environment-friendly and extremely low in cost. Shivakumarswamy et al. (2013) studied the application of arecanut husk fibre as a fixed bed for treating domestic wastewater.

Although arecanut husk were identified, but presently, large heaps of the husk biomass are creating environmental problem due to lack of proper disposal. Unmanaged areca husk left in the plantation caused bad odour and other decay-related problems (Swamy et al. 2004). Such waste biomass can be converted to wealth. For extending the work done in laboratory to field, extensive planning is required. In today's world, for development of any machine or handling of biomass needs characterisation of the material. Hence a small study was undertaken to characterise the arecanut husk of cv. Shreevardhini. The paper presents the methodology adopted and salient findings of the

study. The properties determined were size (length, width and thickness), bulk density, true density, angle of repose, fibre content, tear force and impact energy required to separate fibre from husk.

Materials and Methods:

The husk used in the present study was of arecanut variety Shreevardhini which is extensively grown in coastal areas of Maharashtra, Goa and Karnataka. Husk was procured from the arecanut processing unit based at Shreevardhan, Dist. Raigad (Maharashtra State). Husk was cleaned such that the pedicel attached to the husk was removed and husk with loosened fibres or fluffy in appearance was discarded. The cleaned husk was stored in moisture proof polypropylene bags for storage during the study period. The moisture content of husk was found to be 12 per cent (w.b.). Standard procedures were followed in determination of these properties.

Measurement of Engineering Properties of Husk

Size: Size of the husk was characterized in terms of axial length and width (lateral dimension) which were measured using a Mitutoyo digital vernier caliper (LC 0.01mm). Also husk thickness was measured with Mitutoyo digital micrometer screw gauge (LC 0.001mm). For characterization of size, 40 different samples of husk were drawn randomly.

Bulk density: Mild steel container of inner dimension of 30x30x30cm was used for determination of bulk density. The container was filled with arecanut husk and weighed. The bulk density of husk was calculated as :

$$\rho_{dh} = \frac{W_{dh}}{V_v} \quad (1)$$

Where, W_{dh} is weight of husk in container (kg), V_v is volume of container (m^3) and P_{dh} is bulk density of husk (kg/m^3). The procedure was replicated 10 times and values were recorded. Similar procedure was followed by Balasubramanian (1985) and Aware et al. (2013). The bulk density of water soaked husk (24 h) was also determined by adopting the above procedure and values were recorded.

True density: To determine true density of an individual husk, it was weighed on digital precision balance (LC 0.01g). A sinker of known volume was attached to the husk using a strong and straight metal wire and placed in the flask containing toluene. The volume of toluene displaced and collected in the measuring cylinder gave the exact volume of sinker and husk. The husk was detached from the sinker with wire. This procedure was repeated for 40 randomly drawn sample husks. The true density of husk was calculated as follows:

$$\rho_{th} = \frac{W_{th}}{V_{sh} - V_s} \times 1000 \quad (2)$$

Where P_{th} is true density of husk (kg/m^3), W_{th} is weight of husk (g), V_{sh} is volume of toluene displaced due to sinker and husk (ml), and V_s is volume of toluene displaced due to sinker (ml). The procedure was also adopted by Aware et al. (2013) for determining true density of arecanut fruit and kernel.

Angle of repose: An apparatus was fabricated to determine angle of repose. The apparatus

consisted of mild steel stand with holder ring, inverted cone (funnel) with container to hold the husk. The inverted cone with container was placed in the ring, having sufficient ground clearance. Husk was filled in the inverted cone and container upto the total height of 35 cm from mouth of cone, keeping it closed during filling. After filling of husk, the plate was removed from the mouth of cone. Thereby, husk started falling down and formed a natural heap. This method of angle of repose measurement is piling method (Fraczek *et al.* (2007), Kingsly *et al.* (2006)).

Then the angle of repose was calculated as follows:

$$\theta = \tan^{-1} \left(\frac{2h}{d} \right) \quad (3)$$

Where θ is angle of repose (degree), h is height of heap formed (cm), and d is diameter of heap formed (cm). The procedure was replicated 10 times. Angle of repose of water soaked husk was also obtained in the same manner.

Fibre content: To determine the fibre content, husk was soaked in water for 24 h, so that the water penetrates into the shell as well as loosens the fibre for easy removal. After 24 h, after wiping of water, fibres were carefully removed by hands. After complete removal of the fibres, shell and fibres were dried in hot air oven at 70°C for 24 h. After drying, containers with shell and fibres were closed with lids and transferred to desiccator to cool down. Fibre and shell weights were recorded with digital precision balance (LC 0.01g). Fibre content of husk was calculated as follows:

$$\text{Fibre content, \%} = \frac{\text{Weight of fibres, g}}{\text{Weight of fibres and shell, g}} \times 100 \quad (4)$$

This procedure was adopted for finding fibre content of total 40 husk.

Mechanical properties of husk: The husk behaviour under different methods of force application would help in identifying different machines for intended use of husk and fibre. Keeping this in mind, tear strength and impact energy of husk for fibre separation were measured.

Tear strength: The husk was subjected to tensile loading in lateral orientation of husk (the longitudinal axis of husk was parallel to the direction of load on husk). Tensile loading of husk was carried out by using Shimadzu Universal Testing machine (Shimadzu AGX series, 50 kN capacity). For measurement of tear force in longitudinal position, two husk holders were fabricated to hold husk between hooks and were fixed into the jaws of testing machine. Tensile loading rate of 10 N/s was applied through the cross head speed of 1 cm/min. The testing machine stopped after maximum tensile force required to tear the husk was sensed. The maximum tear force was recorded. The jaws were lowered and husk was removed. The procedure was replicated for a total of 40 randomly drawn husks.

Impact energy of husk required for fibre separation: Impact energy required to separate/pull fibres from husk shell was determined using direct impact testing set-up. The direct impact testing set-up consisted of grooved hollow pipe of 50 cm length, base stand and

rope tied to hook stand for loading of different mass in increment of 500 g, upto 2 kg. During test, husk was kept on the base of set-up and mass of 2 kg was allowed to fall down on the husk from 40 cm height. After every fall of mass, husk was observed to see that whether the fibres became loose and whether it can be separated easily. The number of impacts required to remove fibre from husk were counted and recorded. The impact energy required to separate fibres from husk was calculated as follows:

$$E_{ih} = M_b \times H_b \times N_b \quad (5)$$

Where, E_{ih} is impact energy (kg-m), M_b is mass of impact object (kg), H_b is height of fall of impact object (m), and N_b is number of impacts required to separate fibre from loosened husk. The time required to fall the mass was calculated by use of Newton's law motion (taking initial velocity as 0 m/s). This procedure was also used by Aware (2010) for arecanut fruit. The equation for time required given below.

$$t = \sqrt{\frac{2s}{g}} \quad (6)$$

Where, t is time required to fall of mass (s), S is height of fall of mass (m), u is initial velocity of mass (m/s), and g is acceleration due to gravity (9.81 kg/m^2). The cumulative time (t_{ch}) was determined on the basis of number of impacts imparted to husk for fibre separation. The impact power expended on husk was determined as follows:

$$P_{ih} = \frac{E_{ih} \times 9.81}{t_{ch}} \quad (7)$$

Where, P_{ih} is impact power expended on husk for fibre removal (W), E_{ih} is impact energy (kg-m), and t_{ch} is cumulative time required in respect of number of impacts (s). The impact power required to remove fibre from dry husk and water soaked husk was determined with 40 husks samples. The values were recorded.

Results:

Size of the husk was determined in terms of length, width and thickness. The characteristic values of the size of husk are given in Table 1.

The length of husk varied between 44.63 and 68.06 mm with a mean value of 55.52 mm. The width of husk varied between 32.62 and 64.46 mm with a mean value of 47.04 mm, while the mean value of thickness of husk was 3.01 mm, with range of 2.21 to 4.75 mm. The results of this study regarding size of arecanut husk, when compared with values obtained in respect of length and width of arecanut fruit by Balasubramanian (1985) and Aware (2010), revealed that length and width of arecanut fruit of cv. Shreevardhini were high. This could be attributed to varietal difference.

Bulk density of husk varied between 95.52 to 102.70 kg/m^3 with a mean value of 99.63 kg/m^3 . Whereas, the bulk density of water soaked husk varied between 299.33 to 319.15 kg/m^3 with its mean value of 310.73 kg/m^3 . The bulk density of soaked husk was almost 3.12 times the bulk density of dry husk. The values of these bulk densities can be utilised in the design of feed hopper for arecanut husk. The value of bulk density obtained in the present study was lower than that of the value bulk density of husk reported by Balasubramanian

Table 1: Engineering Properties of Husk

S. N.	Property of Husk		Unit	Value		Std. Dev.
				Mean	Range	
1	Size	Length	mm	55.52	44.63 - 68.06	5.96
		Width	mm	47.04	34.62 - 64.46	6.53
		Thickness	mm	3.01	2.210- 4.750	0.577
2	Bulk density	Dry husk	kg/m ³	99.63	95.52-102.70	2.16
		Soaked husk	kg/m ³	310.73	299.33 - 319.15	6.57
3	True density		kg/m ³	444.97	334.69 - 651.28	68.48
4	Angle of repose	Dry husk	Degree (o)	36.20	35.79 - 37.40	0.57
		Soaked husk	Degree (o)	38.13	35.33 - 41.05	2.48
5	Fibre content		%	80.20	67.39 - 86.11	3.34
6	Tear force		N	62.70	23.40 - 104.57	20.37
7	Energy required for fibre separation	Dry husk	kg-m	13.32	9.6 - 17.6	2.00
		Soaked husk	kg-m	2.2	1.2 - 3.2	0.47

(1985) as 131.5 kg/m³. This confirms the corollary that the size arecanut fruit of cv. Shreevardhini, is higher than that of the arecanut fruit used by latter in his studies. Bulk density is an important parameter of any biological material from processing point of view as it decides the volume bearing capacities of different components of machine to be developed.

The range of true density of husk was 334.69 to 651.28 kg/m³, with a mean value of 444.97 kg/m³, as presented in Table 1. True density of husk indicates the actual particle density. Bigger the difference between true density and bulk density, larger is the pore space between particles, thereby occupying more space of container to handle the material.

Angle of repose was determined for both dry husk and water soaked husk. It can be seen from Table 1 that the angle of repose of dry husk varied between 35.79° to 37.40°, with a mean value of 36.20°. Same way, the angle of repose of water soaked husk was in the range of 35.33° to 41.05°, with a mean value of 38.13°. Hence, as moisture increases, the angle of repose also increases, irrespective of the size and shape. Compared to angle of repose of the fruit, husk has higher angle of repose, requiring more angle of inclination for sliding.

From Table 1, it can be seen that the fibre content in the arecanut cv. Shreevardhini varied between 67.39 to 86.11 per cent, with a mean value of 80.20 per cent. This parameter of arecanut cv. Shreevardhini, is a bench mark for

comparing efficiency of fibre extraction machine. The husk contained evenly distributed and axially arranged fibres from pedicel to apex. Fibres were attached firmly at apex region.

The tear force required to tear-off husk was in the range of 23.40 to 104.57 N, with its mean value of 62.70 N. Lower value of tear force has very little role in designing aspect of machine. The tearing of the husk started from pedicel region. Because the physiological structure of the husk was such that the ends of fibres were free at pedicel region and strongly attached to shell in apex region.

The average energy required in separating fibre from husk varied between 9.6 to 17.6 kg-m, with a mean value of 13.31 kg-m. For water soaked husk, the energy expended to separate fibre was in the range of 1.2 to 3.2 kg-m, with its mean value of 2.2 kg-m (E_{in}). The time required (t) by mass to fall from a distance of 0.4 m found to be 0.2855 s. The cumulative time required for average five (5) numbers of impacts of mass is 1.4275 s. Using equation 7, the power required to separate fibre from soaked husk is 13.88 W. The value was utilised in the determination of the power requirement for fibre separation.

Conclusions

Investigated engineering properties of the arecanut husk cv. Shreevardhini, can be summarized as follows:

1. The values of length, width and width of separated dried arecanut husk varied between 44.63 - 68.06 mm, 34.62- 64.46 mm, and 2.210- 4.750 mm, respectively. The mean values in respect of length,

width and width were 55.52 mm, 47.04 mm, and 3.01 mm, respectively. Reported values confirm that arecanut fruit of cv. Shreevardhini is larger than other reported varieties of arecanut. This could be attributed to varietal difference.

2. Mean values of bulk densities of husk was found to be 99.63 kg/m³ (dry husk) and 310.73 kg/m³ (wet husk). The bulk density of soaked husk was almost 3.12 times the bulk density of dry husk. Being larger size fruit and thereby the husk, bulk density of dried husk of cv. Shreevardhini was lower than that of husk of other varieties.
3. True density varied between 334.69 to 651.28 kg/m³, with a mean value of 444.97 kg/m³. True density of husk was almost 4.5 times that of bulk density of husk. Hence, deformation in husk can considerably reduce volume of husk per unit weight.
4. Angle of repose of dry husk was 36.20° (degrees) and that of water soaked husk was 38.13° (degrees). Although had not much variation, Angle of repose of water soaked husk had more standard deviation value than that of dry husk, underlining that water soaking of husk changes this rheological property.
5. Fibre content of arecanut husk was 80.20 per cent (range 67.39 to 86.11 per cent). Compared to other fruit fibres [cotton (32 per cent), coir (40 per cent)], this fibre content is quiet high.
6. The tear force required to tear-off husk was in the range of 23.40 to 104.57 N, with its mean value of 62.70 N.

7. Energy required to separate fibre from husk was found to be varied between 9.6 to 17.6 kg-m (mean value 13.32 kg-m) and 1.2 to 3.2 (mean value 2.2 kg-m), for dry husk and water soaked husk, respectively. Soaking of husk in water considerably reduced the energy required to separate fibre from, highlighting the benefit of soaking. Power required to separate fibre from soaked husk was 13.88 W.

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