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Physical properties of cashew nut shells

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ABSTRACT : The physical properties of cashew nut shells were studied as it is necessary in handling, drying, heating, CNSL extraction and other relevant processing operations. The physical properties of the cashew nut shell at moisture content of 10.16 per cent (wb) studied were size, surface area, bulk density, angle of repose, co-efficient of friction and terminal velocity. The cashew nut shells were classified into three sizes *i.e.* small, medium and large. The percentages of these sizes found in the commercially available sample of shells were 9.74 per cent, 77.46 per cent and 12.80 per cent, respectively. The average values obtained were 2410 mm^2, 314 kg/m^3 and 4.91 m/s for surface area, bulk density and terminal velocity, respectively. The angle of repose of medium size shells (23.25^0) was quite close to that of control (23.61^0) sample of shells. The co-efficient of friction was observed maximum for mild steel surface.

KEY WORDS : Cashew nut shells, CNSL, Physical properties

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Cashew (*Anacardium occidentale)* is an important plantation crop of India. It is presently grown in an area of 9.23 Lakh hectares with production of about 7.0 Lakh tonnes (CEPC, 2012). This crop was introduced to India during the 16th century. The potential of this crop in the international trade was first realized by India in the early 1900s through the export of cashew kernels. India has the largest area under cashew and stands as the second largest producer of cashew in the world. Vietnam, Ivory Coast and Brazil are the competitors to India for cashew production and export (CEPC, 2012). Cashew processing, using manual techniques, was started in India in the first half of the twentieth century (Nagaraja and Balasubramanian, 2007). India is the first country to develop technology for the extraction of cashew kernels from raw nuts. Today, India is the largest processor and exporter of cashew in the world (Nagaraja and Balasubramanian, 2007; Swain *et al.*, 2007).

Maharashtra ranks first in the production and productivity of cashew nut among all the states of the country. The area under cashew in Maharashtra is about 1.75 lakh hectares and the production is 1.98 lakh MT. The productivity of cashew in Maharashtra is 1186 kg/ha compared to average value of 695 kg/ha for the country (CEPC, 2012).

The cashew nut consists of kernel 20 to 25 per cent, cashew shell 70-75 per cent and testa 2-5 per cent. Hence, the cashew nut shell and the testa are two major by-products of the cashew processing industry. 100 kg of cashew nut processing generates about 70 to 75 kg of cashew nut shell. Shell contains 20-25 per cent oil. The shell of the nut contains a dark reddish brown viscous liquid. It is called the cashew nut shell liquid and it is popularly referred or abbreviated as CNSL (Rajpakse *et al.*, 1977).

The physical properties of biological materials are shape and size, bulk density, porosity, mass of seeds and friction against various surfaces. Physical properties of Agricultural material are useful for designing various material handling, storage and processing machineries. These properties have been studied for various crops such as nutmeg (Abdullah *et al.*, 2010);raw cashew nuts (Aware *et al.*, 2007; Balsubramanian, 2001; Ogunsina and Bamgboye, 2007); groundnut grains (Davies, 2009); castor nut (Olaoye, 2000); pistachio nut and its kernel (Polat *et al.*, 2007).

The published literature for the data on physical properties of cashew nut shells was not available despite an extensive search. These data would be useful in designing the cashew nut shell processing machinery and its relevant unit operation. Therefore, an investigation was carried out to determine physical properties of cashew nut shells.

The knowledge of physical properties of cashew nut shells is necessary in handling, drying, heating, CNSL extraction and other relevant processing operations. The physical properties of the cashew nut shell studied were size, surface area, bulk density, angle of repose, co-efficient of friction and terminal velocity.

METHODOLOGY

The cashew nut shells of about 3.00 MT were procured from the cashew Processing and Training Center (CPTC), Department of Agricultural Process Engineering, College of Agricultural Engineering and Technology, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli. cashew nut shells were cleaned to remove dust and dirt using the air screen cleaner. Cleaned shells were stored for further use in experimentation.

Sample preparation :

Initial moisture content of the shells was determined using standard method (AOAC, 1984). Three samples, each weighing 50 g, were placed in an oven set at 105^{0}C for 24 hrs. The samples were then cooled in a desiccators. The dried samples were weighed and the difference in weight before and after drying was taken to be as a moisture loss. Ratio of moisture loss to weight of wet material in percentage was recorded as moisture content wet basis. The moisture content of the shells per cent (wb) is expressed as follows:

$$\text{Moisture content, \%} \frac{W_1 - W_2}{W_1} \times 100$$

where,

W_1 = Initial weight of sample before drying, g.

W_2 = Weight of sample after drying, g.

The principal dimensions of ungraded cashew nut shells were measured at a particular moisture content using digital vernier caliper with least count of 0.001 mm (Mutuoyo, Japan). Cashew nut shells were first classified into three sizes since the practice of grading the cashew nut prior to processing is not followed in the Konkan region of Maharashtra. Also, the cashew nut shells available were of random size obtained from the ungraded cashew nuts of different varieties. However, cashew nut shells of same size probably may be helpful for better extraction efficiency and better oil recovery. Therefore, the physical properties of the different sizes of the cashew nut shells were determined.

Classification of shells into different sizes :

Classification of the cashew nut shells was done by sieving the cashew nut shells using different sieves. The four sieves used in the present study were of perforation size 25 mm, 20 mm, 16 mm and 12 mm size were used based on the dimensions of the cashew nut shells. Two kg of cashew nut shells were used for each test with ten replications for sieving. The sieves were shaken for 10 minutes using the manual sieve shaker. The sieves were arranged from top to bottom with decreasing perforation size. The weights of samples retained on each sieve were measured and recorded. After the sieving, they were classified into three categories. The cashew nut shells retained on 20 mm sieve were considered as large (L) size shells. The shells retained on 16 mm sieve were considered as medium (M) size shells. The shells retained on 12 mm sieve were classified small (S) size shells. Thus, the shells were classified into three groups based on size namely, small (S), medium (M) and large (L).

Dimensions of the cashew nut shells :

Dimensions of the cashew nut shells classified into three sizes were measured using digital vernier calliper. The length, breadth and thickness of the shells were measured at the moisture content for which they are commercially available. Hundred shells from each size (small, medium and large) were used for the measurement of the principal dimensions.

The geometric mean dimension (D_e) of cashew nut shells was estimated using the relationship (Mohsenin, 1980) as follows:

$$De = (LBT)^{1/2}$$

where:

L = Length of cashew nut shell, mm

B = Breadth of shell, mm

T = Thickness of shell, mm

Determination of surface area (A) :

The surface area of cashew nut shell was measured by tracing the shell on a graph paper by rolling the shell on the graph paper and counting the squares (Mohsenin, 1980; Singhal and Samuel, 2003). Thirty shells of each size (small, medium and large) were used for the measurement of the surface area of cashew nut shell.

Determination of bulk density (ρb) :

The bulk density is important during the handling of the shells for filling in bags and storage. The bulk density was determined by the hectoliter apparatus. A cylindrical container of known volume (1000 ml) was used. It was filled with cashew nut shells from the height of 15 cm. The weight of the cashew nut shells were measured using the electronic weighing balance (Contech, Mumbai) to an accuracy of 0.001 g. The experiment was replicated for 50 times. The bulk density (ρb) was calculated as the ratio of the weight of the cashew nut shells to the volume of the cylindrical container.

Determination of angle of repose :

The angle of repose characterizes the flowing capacity of the material. This property of the shell is essential in determination of the size of the appropriate packaging, handling and storage of the material.The angle of repose was determined using the method mentioned in the IS:6663 (1972) (Kachru *et al.,* 1994). A topless and bottomless cylindrical container of 0.15 m diameter and 0.25 m height was used. The container was placed at the leveled and smooth surface. The cashew nut shells were poured into the container from a certain

height and the container was filled with the cashew nut shells. The flat levels of the cashew nut shells from both sides of the container were measured. The distance of the heap from the top of the container was measured. Test was replicated thirty times for each size of the shells. The angle of repose (ψ) was calculated by the following relationship:

$$\tan^{-1}\psi = \frac{d_3}{100}$$

where:

Height of the pile, $d_3 = d_1 - d_2$

$d_1 = (d_{1a} + d_{1b})/2$

d_{1a} = flat level of the cashew nut shells from one side of the container,

d_{1b} = flat level of the cashew nut shells from the other side of the container.

d_2 = the distance of the heap from the top of the container.

Determination of co-efficient of friction :

The knowledge of co-efficient of friction is necessary in predicting the motion of the material in the handling equipment. It is also important in determining the pressure of the material against the walls of the containers. The static co-efficient of friction of cashew nut shells against four different structural materials, namely mild steel, plywood, sun mica and glass was determined. Test was replicated ten times for each size of the shells with each type of structural material.

The experimental apparatus used in the friction studies consisted of a frictionless pulley fitted on a frame, a bottomless rectangular box, a loading pan and test surfaces. A topless and bottomless plywood box of dimensions 150 x 100 x 40 mm^3 was filled with cashew nut shells and placed on the horizontal test surface. Weights were then added to the loading pan until the box began to slide along the test surface. The normal force applied N_f was the weight of the shells in the box and the frictional force F was the weights added to the pan. The co-efficient of static friction (m) was calculated as :

$$\mu = \frac{F}{N_f}$$

where,

N_f = weight of the shells, g

F = weights added to the pan, g

Determination of terminal velocity :

Terminal velocity was measured using an air column (Fig. A). For each test, a sample (cashew nut shell) of 10 g was dropped into the air stream from the top of the air column (Make: Indosaw, Haryana), and air was blown up in the column to suspend the material in the air stream. The air velocity near the location of the sample suspension was measured by a digital anemometer having a least count of 0.1 m/s (Fos'hat *et al.*, 2011; Gharibzahedi *et al.*, 2010; Isik and Nazmi, 2007).

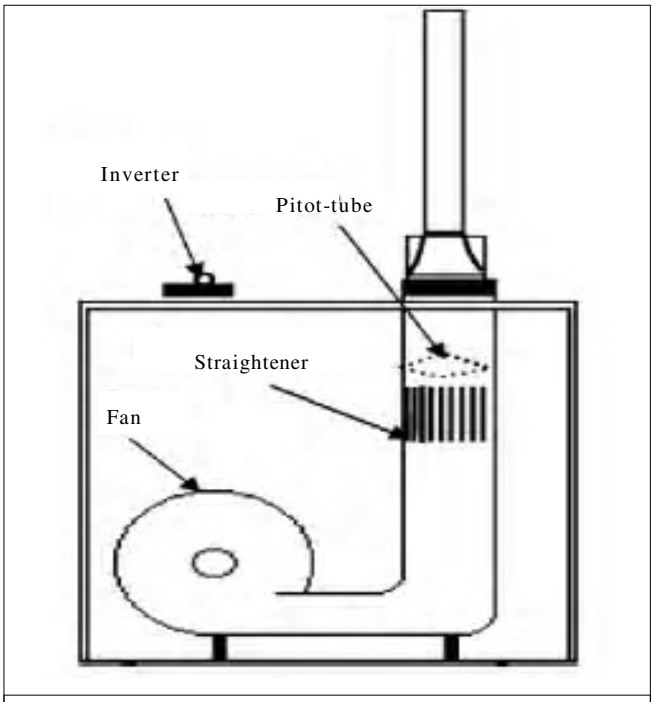

Fig. A: Air column for measurement of terminal velocity of cashew nut shell

■ RESULTS AND DISCUSSION

The moisture content of the cashew nut shells procured for the present investigation was found to be 10.16 per cent (wb). The properties such as principal dimensions, surface area, bulk density, angle of repose, co-efficient of friction and terminal velocity of cashew nut shell were determined at the moisture content of 10.16 per cent (wb) and at room temperature for different shell sizes.

Classification of the cashew nut shells :

The cashew nut shells used for the extraction of oil are not graded. Efforts were made to determine the size of the shells available in the market and classification was made based on the size to see the influence of size on the oil extraction in screw press. Sieves of different sizes (12, 16, 20 and 25 mm) were used for classification. Two kg of cashew nut shells were used for each test of sieving and it was replicated ten times. Mean values of the weight of shells retained on different sieves as shown in Table 1. It is found that 9.74 per cent of the cashew nut shells was having size of 12 to 16 mm, 77.46 per cent of the shells were having size in the range of 16 to 20 mm and 12.80 per cent of the shells were having size larger than 20 mm. Shells were classified based on the sizes in three class namely small, medium and large. Shells having dimensions smaller than 16 mm were classified as small, in between 16 and 20 mm were classified as medium shells and shells having dimensions larger than 20 mm were called as large shells. As

seen from the Fig. 1, the classification of cashew nut shell shows the normal distribution. It is also observed that the major share in the commercially available nonclassified (Control) shells was of the medium sized cashew nut shells.

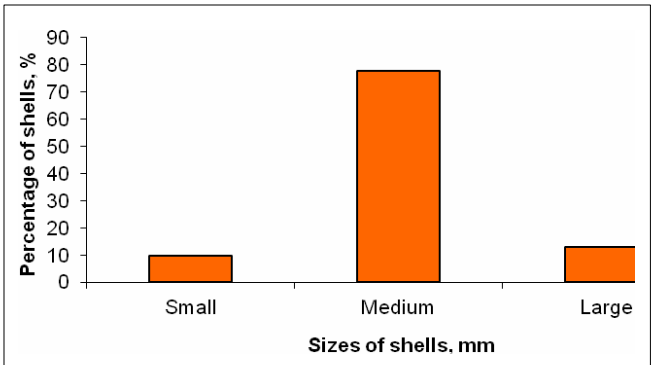

Fig. 1: Size distribution of ceshew nut shells

Dimensions of cashew nut shells for various sizes :

Length, breadth and thickness of the cashew nut shells were measured for 100 shells randomly for all sizes. The average length, breadth and thickness were found to be 30.55, 22.03, and 12.94 mm, respectively for large shells. The corresponding values for the medium size shells were 28.12, 18.55 and 9.12 mm, respectively; and those for small size cashew nut shells were 26.57, 14.57 and 6.19 mm, respectively. The geometric mean diameter (GMD) found to be 20.57, 16.82 and 13.38 mm, respectively for large, medium and small size shells. These results are tabulated in Table 2. It is inferred from the data in Table 1 and Table 2 that the size of the shells analyzed by sieves is quite closer to the classes based on the geometric mean diameter of the cashew nut shells, *i. e.* large size shells having GMD more than 20 mm as these shells were passed through 25 mm sieve and retained on 20 mm sieve. The similar findings were also obtained for the medium and small size shells.

Surface area :

The surface area of cashew nut shell is an important property required in conditioning and extraction. The surface area of cashew nut shell was measured for 30 numbers of shells from each class (large, medium and small) and control sample by tracing the shell on a graph paper by rolling the shell on the graph paper and counting the squares. The results of the surface area of cashew nut shell are given in Table 3. It is observed that the surface area of large shells was 1.4 times larger than those of medium shells and 2.15 times larger than those of small shells. It is also observed that the surface area of medium sized cashew nut shells was quite closer to that of the control sample of shells.

Bulk density :

The bulk density is important property required in handling and storage of the cashew nut shells. The bulk

Table 1: Classification of cashew nut shell

Sr. No.	Size of sieve shell passes through (mm)	Size of sieve on which shells are retained (mm)	Mass of shells (g)	Share (%)	Class of shells designated
1.	25	20	1549.24	12.80	Large
2.	20	16	256.06	77.46	Medium
3.	16	12	194.70	9.74	Small
	Total	….	2000.00	100.00	….

Table 2: Dimensions of cashew nut shell

Sr. No.	Class	Length (mm)	Breadth (mm)	Thickness (mm)	GMD (mm)
1.	Large	30.55± 2.45	22.03± 1.33	12.94±0.36	20.57
2.	Medium	28.12± 1.97	18.55± 0.79	9.12± 0.75	16.82
3.	Small	26.57 ±1.68	14.57 ± 0.91	6.19 ± 0.82	13.38

Table 3: Surface area of shells for different classes of cashew nut shells

Sr. No.	Class	Surface area (mm^2)	S.D.*
1.	Large	3180.00	± 235.50
2.	Medium	2273.30	± 179.90
3.	Small	1480.00	± 242.70
4.	Control	2410.00	± 533.90

*n = 30

density is determined at moisture content of 10.16 per cent (wb) for each class of shells and control sample in 50 replicates. Table 4 shows that the bulk density of small size shells was highest (343.41 kg/m^3) whereas that of large shells was lowest (299.73 kg/m^3). Bulk density of small shells was higher. This may be due to the compactness of the small shells and more number of shells were accommodated in the given volume. The bulk density of medium sized shells was quite close to that of control sample of the shells indicating that the quantity of the control sample of shells constitutes 80 per cent medium sized shells.

Angle of repose :

The angle of repose characterizes the flowing capacity of the cashew nut shells. This property of the cashew nut shell is essential in determination of the relative size of the length (diameter) and height of an appropriate packaging or storage structure for the shells. Angle of repose has influence on the storage containers and hopper design. Angle of repose of cashew nut shells was determined for all the three shell classes (size) and also for the control sample of cashew nut shells. The angle of repose for control sample of cashew nut shell at moisture content of 10.16 per cent (wb) was found to be 23.61^0. Angle of repose of medium size shells (23.25^0) was quite close to that of control sample of shells as seen from Fig. 2. Angle of repose for small size shells was 28.12^0 and that for large size shells it was found to be 20.68^0 as shown in Fig. 2. Olaoye (2000) observed similar trend for angle of repose of castor nut.

Co-efficient of friction :

The knowledge of co-efficient of friction of cashew nut shells is necessary in handling and extraction of oil from the shells in screw press. Co-efficient of friction of cashew nut shells was determined for four types of surfaces *viz.*, mild steel, plywood, sun mica and glass. Results of co-efficient of friction for cashew nut shells at moisture content of 10.16 per cent (wb) obtained for different surfaces are given in Table 5. Type of contact surface and size of shell both have influence on the co-efficient of friction of cashew nut shells. It was found to be on an average 0.51 for mild steel surface, 0.49 for ply wood, 0.47 for sun mica surfaces and 0.46 for glass surface. The co-efficient of friction was observed maximum in case of mild steel surface as shown in the Fig. 3. It was followed by plywood surface and sun mica surface. The glass gave least friction probably due to smooth and polished surface. Balasubramanian (2001) observed similar results in case of cashew nut. Davies (2009) also observed similar results for ground nuts. It was observed that the smoother the structural surface, the lower the co-efficient of friction of agricultural products.

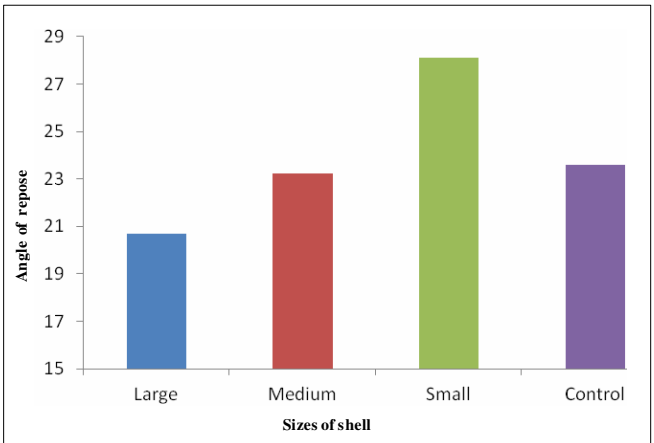

Fig. 2: Angle of repose for cashew nut shell

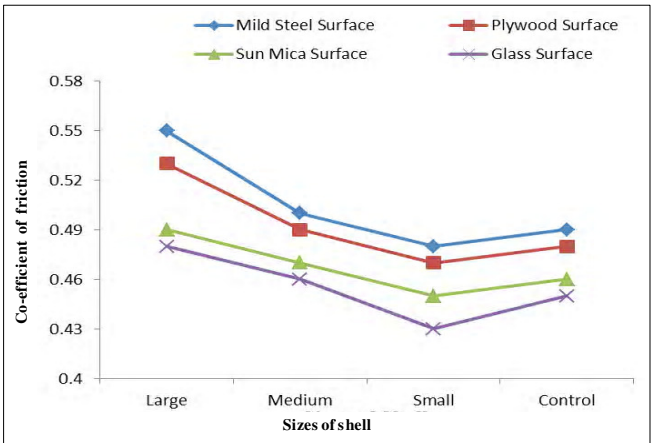

Fig. 3: Co-efficient of friction for cashew nut shells

Table 4: Bulk density of cashew nut shell

Sr. No.	Class	Bulk density (kg/m^3)	S. D.*
1.	Large	299.73	±1.71
2.	Medium	304.72	±1.32
3.	Small	343.41	±1.54
4.	Control	306.72	±1.49
	Mean	313.65	

*n = 50

Table 5 : Co-efficient of friction of cashew nut shells

Sr. No.	Class	Surfaces			
		M. S. surface	Plywood surface	Sun mica surface	Glass surface
1.	Large	0.55	0.53	0.49	0.48
2.	Medium	0.50	0.49	0.47	0.46
3.	Small	0.48	0.47	0.45	0.43
4.	Control	0.49	0.48	0.46	0.45
	Mean	0.51	0.49	0.47	0.46

Table 6: Terminal velocity of cashew nut shells

Sr. No.	Class	Terminal velocity (m/s)	S. D.*
1.	Large	4.37	± 0.09
2.	Medium	4.93	± 0.09
3.	Small	5.51	± 0.09
4.	Control	4.83	± 0.09
	Mean	4.91	± 0.09

*n = 10

Terminal velocity :

Terminal velocity of cashew nut shells at the moisture content of 10.16 % (wb) was measured with the help of seed blower and anemometer. The average terminal velocity of shells of different sizes was found to be 4.37, 4.93, 5.51 and 4.83 m/s for large, medium, small and control samples of shells, respectively as shown in Table 6. As the size of the shells increased, the terminal velocity decreased. The mean value of terminal velocity of the cashew nut shells was 4.91 m/s and that for medium size shells as 4.93 m/s. It depicts that the terminal velocity of medium shells is reprenting the mean value of cashew nut shells sample in general.

Conclusion :

Cashew nut shells were classified based on the sizes in three classes namely small, medium and large. The large shells having size more than 20 mm were found to be 12.80 per cent, the medium shells having size in the range of 16 to 20 mm were 77.46 per cent and the small size shells having size less than 16 mm were 9.74 per cent from the bulk lot of cashew nut shells used in this study.The surface area of large shells was 1.4 times larger than those of medium shells and 2.15 times larger than those of small shells. The mean surface area of the cashew nut shells was found to be 2410 mm^2 for commercially available material. Average bulk density of cashew nut shells is 314 kg/m^3 at the moisture content of 10.06 per cent (wb). The bulk density of medium sized shells was quite close to that of control sample of the shells, since the quantity of the control sample of shells constitutes 80 per cent medium sized shells.The angle of repose for control sample of cashew nut shell at moisture content of 10.06 per cent (wb) was found to be 23.61^0. Angle of repose of medium size shells (23.25^0) was quite close to that of control sample of shells. Angle of repose for small size shells was 28.12^0 and that for large size shells it was found to be 20.68^0.The co-efficient of friction was observed maximum in case of mild steel surface. It was followed by plywood surface and sun mica surface. The glass gave least friction probably due to smooth and polished surface. As the size of the shells increased, the terminal velocity decreased. The mean value of terminal velocity of the cashew nut shells was 4.91 m/s and that for medium size shells as 4.93 m/s. It depicts that the terminal velocity of medium shells is reprenting the mean value of cashew nut shells sample in general.

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REFERENCES

Abdullah, M.H.R.O., Ch'ng, P.E. and Lim, T.H. (2010). Determination of some physical properties of nutmeg (*Myristica fragrans*) seeds. *Res. J.Appl. Sci., Engg.& Tech.*, **2**(7): 669-672.

Aware, V. V., Nalawade, S. M., Powar, A. G., Chaudhari, N.C. and Jadhav, S.K. (2007). Determination of physical-mechanical properties of raw and steamed cashew nut. *The Cashew, DCCD Cochin,* **21** (3): 6-12.

Balasubramanian, D. (2001). Physical properties of raw cashew nut. *J. Agric. Eng. Res.,* **78**(3): 291-297.

Davies, R. M. (2009). Some physical properties of groundnut grains. *Res. J.Appl. Sci. Engg.&Tech.,* **1**(2): 10-13.

Fos'hat, M., Etemad,V., Gharibzahedi, S.M.T. and Ghahderijani, M. (2011). Physical, mechanical and aerodynamic properties of Acorn (*Quercus suber* L.) as potentials for development of processing machines. *Aust. J. Crop Sci.*, **5**(4): 473-478.

Gharibzahedi, S.M.T., Etemad, V., Mirarab-Razi, J. and Fos'hat, M. (2010). Study on some engineering attributes of pine nut (*Pinus pinea*) to the design of processing equipment. *Res. Agric. Engg.,* **56** (3): 99–106.

Isik, E. and NazmiI (2007). Moisture dependent physical and mechanical properties of dent corn (*Zea mays* var. *indentata* Sturt.) seeds (Ada-523). *Am. J. Food Tech.*, **2**: 342-353.

Kachru, R.P., Gupta, R.K. and Alam, A. (1994). *Physico-chemical constituents and engineering properties of food crops*. Scientific Publishers, Jodhpur (RAJASTHAN) INDIA.

Mohsenin, N.N. (1980). *Physical properties of plant and animal materials*. Gordon and Breach Science Publishers, NEW YORK, USA, Vol. **1**.

Nagaraja, K.V. and Balasubramanian, D. (2007). Processing and value addition in cashew. National seminar on Research, Development and Marketing of Cashew, 20th – 21st November, pp.89-92.

Ogunsina, B.S. and Bamgboye, A. I. (2007). Effects of pre-shelling treatment on the physical properties of cashew nut (*Anacardium occidentale*). *Internat. Agrophysics,* **21**, 385-389.

Polat, R., Aydin, C.and Erolak, B. (2007). Some physical and mechanical properties of pistachio nut. *Bulgarian J. Agric. Sci. National Center Agrarian Sciences*, **13**: 237-246.

Rajapakse, R.A., Gunatillake, P.A. and Wijekoon, K. B. (1977). A Preliminary study on processing of cashew nuts and production of cashew nut shell liquid (CNSL) on a commercial scale in Sri Lanka. *J. Ntn. Sci. Coun.Sri Lanka*, **5** (2): 117-124.

Singhal, O.P. and Samuel, D.V.K. (2003). *Engineering properties of biological materials.* Saroj Prakashan. Allahabad (U.P.) INDIA 646-647.

Swain, S.K.,Gupta, J.P. and Sahoo, P.K. (2007). Scope for modernization of cashew nut processing in Orissa. National seminar on Research, Development and Marketing of Cashew, 20th – 21st November, pp.98-99.

■ WEBLIOGRAPHY

CEPC (2012). About cashew and cocoa-statistics. Cashew nut Exports Promotion Council of India. *http://www.cashewindia.org/*php/cepcContents.php?CatID=29.

Olaoye, J.O. (2000). Some physical properties of castor nut relevant to the design of processing equipment. *J. Agric. Engg. Res.,* **77** (1): 113-118. *http://www.idealibrary.com.*

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