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Physical characterization of chironji (*Buchanania lanzan*) nut and kernels

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Buchanania lanzan (Chironji), a member of family *Anacardiaceae*contains a hard nut that on decortication yields kernel containing about 52 per cent oil and used as a substitute for olive and almond oil while the whole kernel is used in sweet-meals. Although, the chironji nuts and kernels have been used extensively but the printed literature on their physical and engineering properties is scarce. In the present study, attempt has been made to generate primary data on physical and engineering properties which could be used for developing processing machinery(s). The initial moisture content of chironji nuts and kernels was found to vary from 6.60 per cent to 11.07 per cent and from 2.77 per cent to 2.99 per cent (db), respectively. The mean length, width and thickness of chironji nuts were found to be 10.19, 9.12 and 7.32 mm, respectively while corresponding parameters for chironji kernels were 6.80, 5.01 and 4.66 mm. The sphericity and roundness of chironji nuts were found to be 81.85 per cent and 79.45 per cent, respectively while for kernel were 77.08 per cent and 76.41 per cent. The average chironji nut mass was 0.33 gand kernel 0.07 g.

Key Words : Chironji, Physical properties, *Buchanania lanzan*

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INTRODUCTION

Buchanania lanzan (Chironji), a member of family Anacardiaceae is a commercially useful tree which is distributed through out India, Burma, and Nepal (Hemavathy and Prabhakar, 1988). The plant grows on yellow sandy-loam soil. In India it is commonly found in the dry forests of Jharkhand, Madhya Pradesh, Chattisgarh, Varanasi and Mirzapur districts of Uttar Pardesh etc. (Pandey, 1985).

The kernel contains about 52 per cent oil (Wealth of India, 1948). The kernel oil is used as a substitute for olive and almond oils, while the whole kernel are much used in sweet-meats as a substitute for almond kernels. Oil is extracted from the fruits of *Buchanania lanzan*and in India they are known as "*char*" whereas the nuts are known as "Chironji". Although, the chironji nuts and kernels have been used extensively but the printed literature on their physical and engineering properties is scarce. In the present study attempt has been made to generate primary data on physical and engineering properties which could be used for developing processing machinery(s).

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METHODOLOGY

Chironji nuts were purchased from a village market of West Singhbhum district of Jharkhand during the spring season in 2007. The chironji nuts were cleaned manually to remove all foreign matters such as dust, dirty, stones and chaff as well as immature infested and broken nuts. The chironji nuts were soaked overnight in plain water. Skin was removed by rubbing on the rough surface of jute bag. The nuts were washed and dried.

Initial moisture content :

The initial moisture content of chironji nuts and kernels

Nomenclature			
AOAC	Association of official analytical chemists	Ac	smallest circumscribing circle, mm^2
D_p	geometric mean diameter (GMD), mm	Ap	largest projected area of each trace, mm^2
Mc	moisture content, %	ρ_t	true density, $kg.m^{-3}$
Φ	degree of sphericity	ρ_b	bulk density, $kg.m^{-3}$
L	length, mm	£	porosity
W	width, mm	V_t	terminal velocity
T	Thickness, mm	N	normal force in internal friction
R_i	roundness index	F	frictional force
R_a	aspect ratio	μ	coefficient of internal friction

was determined by using standard method of moisture determination (AOAC, 1975).The five lots of about 30 – 40 nuts were taken out from bulk. From these lots 20 nuts were selected randomly to obtain 100 nuts and kernels for conducting the experiment.

Size and shape indices :

The nut and kernel size, interms of the three principal axial dimensions, that is length, breadth and thickness as shown in Fig. 1 were measuredusing the grain shape tester (K 200, Japan) with an accuracy of 0.01 mm. The seed shape was alsodetermined in terms of its geometric mean diameter, sphericity,roundness and aspect ratio.The geometric mean diameter (D_p) of the seed was calculated by using the following relationship (Mohsenin, 1970) :

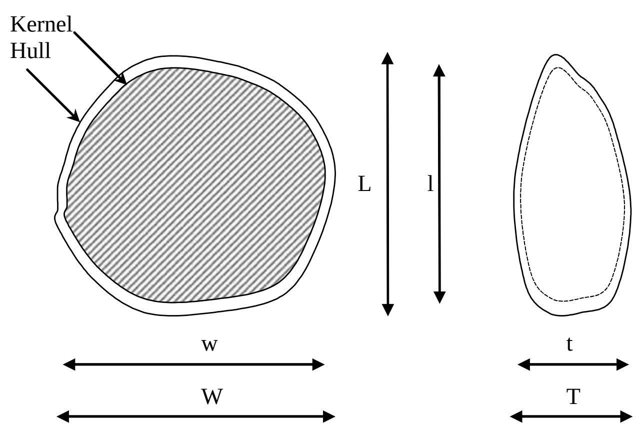

Fig. 1 : Chironji nut and kernel with characteristics dimension

$$D_p = (LWT)^{\frac{1}{3}} \quad ......(1)$$

The degree of sphericity (Φ) was calculated using the following formula as described by (Mohsenin, 1970) :

$$\Phi = \left(\frac{LWT}{L}\right)^{\frac{1}{3}} \times 100 \quad ......(2)$$

where, L is the length, W is the width and T is the thickness.

Roundness index (R_i) :

To obtain the roundness index, each seed was placed on a sheet of tracing paper in its natural rest position and the edges carefully traced with a sharp thin pencil. The largest inscribed circle and the smallest circumscribing circle were constructed for each of the traces. The area of the smallest circumscribing circle (A_c) was calculated; while the largest projected area of each trace (A_p) was measured using a planimeter. The roundness index (R_i) was computed (Shepherd and Bhardwaj, 1986) as

$$R_i = \frac{A_p}{A_c} \times 100 \quad ......(3)$$

Aspect ratio (R_a) :

The aspect ratio (R_a) was calculated (Maduako and Faborode, 1990) as :

$$R_a = \frac{b}{a} \times 100 \quad ......(4)$$

where, a =Length, b= Width

True and bulk densities :

The true density of a nut or seed is defined as the ratio of the mass of a sample of a nut or seed to the solid volume occupied by the sample. The nut and seed volume and their true density were determined using the liquid displacement method. Toluene (C_7H_8) was used in place of water to avoid any absorption by seeds. Also, its surface tension is low, so that it fills even shallow dips in a seed and its dissolution power is low (Ougt, 1998; Sitkei, 1986). The bulk density is the ratio of the mass of a sample of seed to its total volume. The bulk density was determined using the mass volume relationship (Mohsenin, 1970) by filling an empty plastic container of predetermined volume and tare weight with the seeds by pouring from a constant height, striking of the top level and weighing.

Porosity (ε) :

The porosity (ε) of bulk seed was computed from the values of true density and bulk density using the relationship given by Mohsenin (1970) as follows:

$$\varepsilon = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \qquad ......(5)$$

where, ρ_t = true density, ρ_b = Bulk density

Terminal velocity (V_t) :

The terminal velocities of chironji nut, kernel and hull were measured at 5.31, 2.93 and 9.11 per cent db moisture content respectively using an air column. A few seeds (or kernels) were dropped from the top of a 75 mm diameter, 1 m long glass tube. The air flowed upwards in the tube from bottom to top and the air velocity at which the major fraction of the sample remained suspended was recorded by a hot-wire anemometer (Nihon Kagaku Kogyo, Japan) having a least count of 0.1 m/s. Five replications were taken for each sample . The range of terminal velocities were also measured because it will be utilize for the design of blowers for aeration and drying gadgets.

Hardness :

Compressive strength of seed was considered an important mechanical property in relation to seed breakage during extraction. The compressive strength of the seed was measured by using Instron Universal Testing machine. The Instron machine consist of a rectangular plate, flat, clamps and digital display unit. The load cell was attached with the help of a flat and clamps to the vertically moving upper cross-head of the Instron machine. The base of the Instron machine was used as the base for placement of chironji nut.

Angle of repose :

To determine the emptying or dynamic angle of repose, a sunmica box of 300×300×300 mm, having a removable front panel was used. The box was filled with the sample, and then the front panel was quickly removed, allowing the seeds to flow and assume a natural slope. The angle of repose was calculated from the measurement of the maximum depth of the free surface of the sample and the diameter of the heap formed outside the container. All these experiments were replicated five times, unless stated otherwise, and the average values are reported at the set moisture content.

Co-efficient of external friction on different surfaces :

The static co-efficient of friction for nut, kernel and hull was determined against surfaces of three structural materials, namely mild steel sheet, canvas sheet and sunmica. A galvanized iron cylinder of 100 mm diameter and 50 mm height filled with the sample was placed on an adjust Table tilting plate, faced with the test surface. The cylinder was raised slightly so as not to touch the surface. The structural surface with the box resting on it was inclined gradually with a screw device until the box just started to slide down and the angle of tilt was read from a graduated scale.

Co-efficient of internal friction :

The experimental setup used by Sherif (1996) and Manimehalai and Viswanathan (2006) for the measurement of co-efficient of internal friction of cassava starch and fuzzy cottonseed, respectively, was used to measure the co-efficient of internal friction of chironji nuts, kernels and hull at a particular moisture contents. The apparatus consisted of two cylinders, with one being a stationary and the other one to slide on the stationary one. The diameter and height of the cylinders were 50 mm and 55 mm, respectively. Through a pulley-rope arrangement with a loading pan, the top cylinder was made to slide on the stationary one. Both the cylinders were placed in position and filled the sample without any compaction.The mass of the chironji nuts, kernels orhull contained in the top cylinder was the normal force (N) acting on the top layer of the same material contained in the stationary cylinder. The incremental load applied in the loading pan to slide the top pan was the frictional force (F). The force required to slide the empty top cylinder was subtracted from the frictional force, to get the actual frictional force to overcome the friction due to the material. Using the Eq. (6), the co-efficient of internal friction, μ was calculated.

$$\mu = \frac{F}{N} \qquad (6)$$

where, μ, is the co-efficient of internal friction, N is the normal force in internal friction (N), and F is the frictional force in internal friction (N). Mean of five replications were reported and for each replication, the chironji nuts, kernels orhullin the sample container was emptied and refilled with a different sample. A similar experimental set up was used to determine the internal friction properties of the ground marigold petals Zou and Brusewitz (2001) and soybean and corn meal Molenda *et al.* (2002). However, in their experimental setup, shearing was done at constant speed using mechanical drive.

Proximate composition :

The Chironji nuts were manually dehulled to obtain whole kernels and hulls. Seeds were analyzed for their proximate analysis using AOAC (1975) methods. Average values of five measurements are reported on a moisture-free basis.

Size distribution :

The lengths of a random sample of 100 nuts were measured using the grain shape tester (K-200, Japan). The nuts, its kernel and hull were weighed on an electronic balance to ascertain their proportions. These seeds were graded into large, medium and small size based on their lengths to enable the effect of size on some of the properties to be studied.

Moisture conditioning :

A series of 20 g samples of seeds were soaked in tap water for different periods of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 hours. The seeds were lightly dabbed with blotting paper to remove adhering water. The moisture absorbed bythe seeds and their fractions was determined using an analytical balance. Seeds soaked for 12 hours (wet seeds) were used to study the effect of conditioning on some of the properties.

OBSERVATIONS AND ASSESSMENT

Some properties of chironji nuts and that of kernels are presented in Table 1 and Table 2 respectively. From the Table 1 it could be observed that the moisture content of nut was found to vary from 6.60 per cent to 11.07 per cent (average 8.93 per cent db). The average individual nut weight was observed to be 0.33g however great variation (0.15 to 0.39 g) was observed which may be attributed to differences in the size, shape and maturity. The chironji kernel is covered with a hard seed coat (rind). The rind constitutes the major fraction (60.0 to 84.6 %) of nut with an average of 75.8 per cent. The thickness of rind varies from 1.28 to 1.92 mm (average 1.62 mm).

The mean length, width and thickness of chironji nutswere found to be 10.19, 9.12 and 7.32 mm, respectively. Corresponding values for the oilbean seed was 65.4, 41.3 and

Table 1 : Some physical properties of chironji nuts

Physical property	Number of observations	Mean value	Maximum value	Minimum value	Std. deviation
Moisture content, wt% (db)	5	8.93	11.07	6.60	2.58
Length, mm	100	10.19	11.93	8.00	1.05
Width, mm	100	9.12	10.91	7.00	0.66
Thickness, mm	100	7.32	8.92	6.10	0.59
GMD, mm	100	8.77	10.74	6.77	1.12
Sphericity, %	100	81.85	91.00	80.40	3.05
Roundness, %	100	79.45	88.70	70.70	6.54
Aspect ratio, %	100	1.12	1.28	1.02	0.07
True density, kg^{-3}	30	884.3	926.67	758.60	19.10
Bulk density, kg^{-3}	30	578.3	585.10	571.00	4.99
Mass, g	100	0.33	0.39	0.15	0.11
Volume, ml	30	0.26	0.42	0.15	0.10
Porosity, %	30	33.82	36.86	24.73	5.67
Hull (rind) thickness, mm	100	1.62	1.92	1.28	0.31
Hull (rind) weight, g	100	0.25	0.33	0.09	0.10

Table 2 : Some physical properties of chironji kernels

Physical property	Number of observations	Mean value	Maximum value	Minimum value	Std. deviation
Moisture content, %(db)	5	2.81	2.99	2.77	0.53
Length, mm	100	6.80	8.25	5.40	0.90
Width, mm	100	5.01	5.40	4.78	0.22
Thickness, mm	100	4.66	5.35	4.10	0.47
GMD, mm	100	5.43	6.31	4.67	0.49
Sphericity, %	100	77.08	81.80	69.10	4.59
Roundness, %	100	76.41	80.01	74.60	3.54
Aspect ratio, %	100	1.37	1.54	1.31	0.10
True density, kg^{-3}	30	778.50	802.50	612.30	93.88
Bulk density, kg^{-3}	30	516.40	518.8	513.50	2.01
Mass, g	100	0.07	0.10	0.04	0.02
Volume, ml	30	0.09	0.11	0.09	0.01
Porosity, %	30	29.60	35.35	16.13	7.70

13.7 mm (Oje and Ugbor, 1991), while 7.98, 5.95 and 5.82 mm were reported for Bengalgram (Dutta *et al.*, 1988). The chironji nutis thus smaller than theoilbean seed but bigger than Bengalgram. The importance of theseand other characteristic axial dimensions would be useful in determiningaperture sizes and other parameters in machine designand have been discussed by Mohsenin (1970). The sphericity and roundness of chironji nut were found to be 81.85 per cent and 79.45 per cent, respectively. These values are muchhigher than the corresponding values asreported for oilbean seed 60.5 per cent and 40.0 per cent (Oje and Ugbor, 1991) and for gram74 per cent and 70 per cent (Dutta *et al.*, 1988). The high sphericity of the chironji nut is indicative of the tendency of the shape towards asphere. Furthermore, the shape indices indicate that the chironji nut may betreated as an equivalent sphere like gram for an analytical prediction of its drying behaviour.The average chironji nut mass was 0.33g. As expected, this value is much smaller than 0.713g reported for gram and the 20.2 g reported for oilbean seed. The nut true density, bulk density and porosity were 884.3,578.3 kg/m^3 and 33.82 per cent, respectively. These values are lower than the corresponding values of 1311, 780 kg/m^{3}and 40.5 per cent reported for gram (Dutta *et al.*, 1988), and1578-1623, 830-886 kg/ m^{3}and 45-49 per cent reported forthe three pearl millet varieties (Jain and Bal, 1997). The lower porosity or percentage of volume of voids inthe chironji nut may be due to the higher sphericity androundness, which ensure a more compact arrangementof the kernels.

From the Table 2 the chironji kernel length, width and thickness were found to be 6.80, 5.01 and 4.66 mm, respectively. The chironji kernel sphericity and roundness were found to be 77.08 per cent and 79.45 per cent, respectively. The high roundness indicates that the corners of the kernel are round rather than sharp. Taken along with the high aspect ratio (which relates the kernel width to length), it may be deduced that the chironji kernels will rather roll, like gram, than slide on their flat surfaceslike oilbean seed. This tendency to either roll or slide isvery important in the design of hoppers. The average weight of chironji kernels was found to be 0.07g.

The experimental results for the terminal velocity are presented in the Table 3. The terminal velocity was significantly lower for kernels than that of nuts and hulls.

Table 3 : Terminal velocity for chironji nuts (*Buchanania lanzan*)

Components	Terminal velocity range, ms^{-1}	
	Range	Mean
Nuts	18.5 – 22.3	20.4
Kernels	12.3 – 17.1	14.7
Rind/Hull	16.2 – 21.4	18.8

The hardness of chironji nuts with or without skin as well as oven dried was presented in Table 4.The experimental results for angle of repose with respect to moisture content are presented in Table 5. The experimental values of angle of repose for other grains as extracted from the pertinent literature are also compared. The emptying angle of repose of oilbean (Oje and Ugbor, 1991), gram (Dutta *et al.*, 1988) and wheat (Nelson, 1980) are found to be 17, 6, 11 degree, respectively.

Table 4 : Hardness of chironji nuts (*Buchanania lanzan*)

Types of chironji nuts	Hardness kgmm^{-2}
Nuts (with skin having m.c, 22.26 wt% (db)	42.0
Nuts after drying till constant weight	40.2
Nuts (without skin having m.c, 10.05wt% (db)	38.1
Nuts after drying till constant weight	33.3

Table 5 : Angle of repose of chironji nut (*Buchanania lanzan*)

Component	Moisture content %db.	Angle of repose, degree
Nut	7.31	28.1
Kernel	2.93	20.1
Hull	9.11	38.3

The static coefficients of friction for chironji components, determined with respect to three surfaces, are presented in Table 6.

Table 6 : Static co-efficient of friction of chironji nut (*Buchanania lanzan*)

Component	External friction			Internal friction
	Sunmica	Mild Stainless Sheet	Canvas Sheet	
Nut	0.246	0.590	0.664	0.654
Kernel	0.178	0.239	0.433	0.550
Hull	0.220	0.531	0.643	0.880

The proximate analysis of the chironji nut, kernels and hull used in the study is given in Table 7. Kernels contain mainly fat and protein while the hull contains fibre.The size distribution of the chironji nut sample is given in Table 8.The water absorbed by different components of the seed during soaking is tabulated in Table 9. It was also observed that the kernel became soft during soaking.

Table 7 : Proximate analysis (% db) of Chironji nut (*Buchanania lanzan*) on moisture free basis

Component	Nuts	Kernels	Hulls
Minerals	5.02	2.70	15.60
Ether extract	12.68	52.13	0.62
Crude fibre	64.78	9.24	70.91
Protein (N X 6.25)	9.56	28.12	1.68
Carbohydrate (by difference)	7.96	7.81	11.19

Table 8 : Size distribution of chironji nut (*Buchanania lanzan*)

Size	Length (cm)	(%) Sample		Average seed wt. (mg)	Length to width ratio	Average thickness (cm)	Kernel to hull ratio (wt/wt)
		No. (%)	Wt (%)				
Large	>7.1	42	16.19	377.46	2.06	4.90	0.33
Medium	6.7-7.1	28	75.22	312.87	1.63	4.33	0.28
Small	<6.7	30	8.59	292.17	1.7	3.68	0.267

Table 9 : Moisture contents of dry seeds and of wet seeds soaked for 12 hours and their fractions

Component	% moisture in		% gain in moisture during soaking
	Dry seed	Wet seed	
Nut	7.37	25.67	26.27
Kernel	8.27	48.18	37.24
Hull	8.87	24.95	22.07

Conclusion :

The initial moisture content of chironji nuts and kernels was found to vary from 6.60 per cent to 11.07 per cent and from 2.77 per cent to 2.99 per cent (db), respectively. The moisture content in the kernels is less in comparison of hull, due to high oil content in kernels. The mean length, width and thickness of chironji nuts were found to be 10.19, 9.12 and 7.32 mm, respectively while corresponding parameters for chironji kernels were 6.80, 5.01 and 4.66 mm. The sphericity and roundness of chironji nuts were found to be 81.85 per cent and 79.45 per cent, respectively while for kernel were 77.08 per cent and 76.41 per cent. The terminal velocity for the chironji kernels (12.3 to 17.1) was significantly lower than that nuts (18.5 to 22.3) and hull (16.2 to 21.4), respectively. The angle of repose of the chironjinuts, kernels and hull were found to be 28.1, 20.1 and 38.3 respectively.The average chironji nut mass was 0.33 g and kernel 0.07 g.

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