International Journal of Advanced Research in Biological Sciences
ISSN : 2348-8069
www.ijarbs.com

Research Article

Effect of moisture content on the engineering properties of Cashew Nuts

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Abstract

The study was conducted to evaluate physical properties of graded and ungraded cashew nuts under different moisture contents (6-10%, db). The average length, width, thickness, geometric mean diameter, sphericity and mass of 100 seeds under graded nuts category ranged 30.51-31.94 mm, 23.84-24.42 mm, 16.50-18.38 mm, 22.39-23.82 mm, 0.75-0.92 and 488.6-548.8 g as the moisture content increased from 6%-10% d.b., respectively and similar reading w.r.t ungraded nuts were 27.28 to 32.13 mm, 17.81 to 21.91 mm, 11.45 to 14.13 mm, 17.72 to 22.22 mm, 0.64 to 1.18, 365.3 to 385.28 g, respectively. At the above moisture range, as the bulk density decreased linearly from 613 to 590 kg/m^3, true density increased linearly from 1066 to 1107 kg/m^3, respectively. The porosity was increased from 41.7 to 46.7% and coefficient of friction, angle of repose increased from 0.55° to 0.63° and 23.9 to 28.6°, respectively and the similar properties w.r.t ungraded nuts were bulk density (613 to 590 kg/m^3), true density (934 to 969 kg/m^3), porosity (41.7 to 46.7%), coefficient of friction (0.44 to 0.52°) and angle of repose (20.9 to 24.6°), at the moisture range 6 to 10%, respectively.

Keywords: Cashew nuts, density, porosity, mechanical properties, moisture

Introduction

Cashew *(Anacardium occidentale L.)* is an evergreen tropical tree though cashew originally belongs to Brazil, it has established well in Indian peninsular soils, and has been exploited to the maximum by Indians. In India, the cashew is grown mainly in peninsular coastal states like Kerala, Karnataka, Goa, Maharashtra, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal. Total area in India under cashew cultivation is about 0.85 million ha with annual production of 0.63 million tonnes giving average productivity 820 kg/h with highest productivity reported in Maharashtra (1500 kg/ha). Cashew Nut Shell Liquid (CNSL) or cashew shell oil is a natural resin found in the honeycomb structure of the cashew nut shell. CNSL contains 90% anacardic acid and 10% cardol. CNSL is used in brake lining of cars because it absorbs heat efficiently and is also used in paints enamels and lacquers (Nagaraja, 2007). Cashew kernel contributes about 611 kilocalories energy foe 100 g. It consists of moisture (5.9%), protein (21%), fat (47%) and carbohydrates (22%) apart from some vitamins. It is a rich source of minerals like calcium, magnesium, phosphorus, potassium, sodium and iron (Nagaraja, 2007). Mohsenin *et al.* (1970) stated that the increasing economic importance of food material for their handling, storage, processing, preservation, quality evaluation, distribution, marketing, and utilization a better knowledge of the physical

properties of these material are essential to understand. The properties of different types of nuts have been determined by other researchers; neem nut (Visvanathan *et al.*, 1996); bambara groundnut (Barye *et al.*, 2001); mahaleb (Aydin *et al.*, 2002); hazel nuts (Aydin, 2002); areaca nuts (Kaleemullah *et al.*, 2002); almond nut (Aydin, 2003); *balanites aegyptiaca* nuts (Aviara *et al.*, 2005); pine nut (Ozguven *et al.*, 2005); pistachio nut (Kashaninejad et al. 2006). The moisture content in the cashew nuts plays a major role in the storage of the nuts for longer duration. Knowing the moisture dependency is useful for further investigation on export and processing of the cashew nuts. Thus, the objective of this study was to investigate some moisture-dependent physical properties of cashew nuts, namely, axial dimensions, sphericity, volume, 1000 seed mass, bulk density, true density, porosity, angle of repose, the static coefficients of friction as a function of moisture content. These data will determine the behaviour of the cashew nuts during processing.

Materials and Methods

Fully matured, good quality Ivory Coast origin cashew nuts were procured from M/S Kalbhavi Cashews Industries, Mangalore for conducting experiments. Well dried raw nuts were stored in plastic drums to avoid the possible moisture migration into the nuts and also to prevent insect attack. The nuts were graded manually to get uniform sized nuts for the research study. Then the initial moisture contents of the nuts were determined by oven drying at 105±1 ^{o}C for 24 h (Ozarlan, 2002). The initial moisture content of the seeds was 6% d.b. Moisture content of raw cashew nut was determined by toluene distillation method as described in AOAC (1995). All the physical properties of the nuts were determined at three moisture contents in the range of 6 to 10% d.b. with three replications at each moisture contents. The following methods were used to determine physical properties of cashew nuts.

Size, geometric mean diameter, sphericity

To determine the average size of the nut, a sample of 100 graded (25 – 35 mm length) and ungraded raw cashew nuts were randomly picked and their three major dimensions namely, length (*l*), width (*b*) and thickness (*t*) were measured using a digital vernier caliper (Make:Mitutoyo Corporation, Japan; Model:CD-6BS) having a least count of ±0.01 mm.

The geometric mean diameter (D) of raw cashew nut was determined using the following expression (Mohsenin, 1970),

$$D = (lbt)^{\frac{1}{3}} \quad \ldots\ldots 1$$

Sphericity (S) of the raw cashew nut was calculated using the following equation (Mohsenin, 1970),

$$S = \frac{(lbt)^{\frac{1}{3}}}{l} \quad \ldots\ldots.. 2$$

Shape

The shape of raw cashew nut was determined through visual observations and by comparing the nut shape with standard shapes given by Kachru (1994).

Weight of 100 nuts (Test weight)

The mass of 100 individual cashew nuts was measured for both graded and ungraded nuts at two different moisture contents of 6 and 10% using an electronic balance (Make : RADWAG, Poland; Model:PS200/2000/C/2) having an accuracy of ±0.001g. The measurements were replicated 3 times and the mean values were computed as test weight.

True density

The true volume of cashew nut was first measured by toluene displacement method. 50 ml of toluene was taken in a 100 ml measuring jar and pre-weighed 10 cashew nuts were dropped inside the jar. The change in the level of toluene in the measuring jar was recorded as true volume and the true density of the cashew nut was calculated using the formula (Mohsenin, 1970),

$$\text{True volume of nuts (ml)} = \begin{Bmatrix}\text{Initial toluene level}\\ \text{in measuring jar}\end{Bmatrix} - \begin{Bmatrix}\text{Final toluene level}\\ \text{in measuring jar}\end{Bmatrix} \quad \ldots\ldots 3$$

$$\text{True density (kg/m}^3\text{)} = \frac{\text{Weight of cashew nuts (kg)}}{\text{True Volume of nuts (m}^3\text{)}} \quad \ldots\ldots.. 4$$

Bulk density

The bulk density was determined as per the method described by Mohsenin (1970). The raw cashew nuts were filled into a container of standard size 10 cm ×10 cm ×10 cm up to the top level. The excess nuts were

removed off so that the top surface was perfectly level and then the nuts in the container were weighed by using an electronic balance. The bulk density was calculated using following formula:

$$\text{Bulk density (kg/m}^3\text{)} = \frac{\text{Weight of nuts (kg)}}{\text{Volume of nuts (m}^3\text{)}} \quad \text{……..5}$$

Porosity

The porosity, also known as the packing factor and it was determined from bulk density and true density of raw cashew nuts using the following expression (Mohsenin, 1970),

$$\text{Porosity (\%)} = \frac{\text{True density} - \text{Bulk density}}{\text{True density}} \times 100 \quad \text{..6}$$

Angle of repose

The angle of repose was the angle between the base and the slope of the cone formed on a free vertical fall of the granular material to a horizontal plane. The angle of repose indicates the cohesion among the individual units of a material. Higher the cohesion, higher is the angle of repose. The dynamic angle of repose of cashew nut was measured by the 'emptying method'. A cylinder was placed over a plain surface and cashew nuts were filled in. The cylinder was raised slowly allowing the sample to flow down and form a natural slope. The dynamic angle of repose was calculated from the height and diameter of the pile as,

$$\theta = \tan^{-1}\frac{2h}{D} \quad \text{……..7}$$

Where, θ - Angle of repose (º),
h - Height of the pile (m),
D - Diameter of the pile (m).

Co-efficient of static friction

The coefficient of static friction was determined using the method described by Kachru (1994) and was calculated using the formula,

$$\text{Coefficient of static friction, } \mu = \frac{W2 - W1}{W} \quad \text{…..8}$$

Where,
μ = Coefficient of static friction
W1 = weight to cause sliding of empty smaller box, kg
W2 = weight to cause sliding of filled smaller box, kg
W = weight of the material inside the smaller box, kg

Statistical Analysis

The statistical analysis of data generated in this study was carried out using the *Agress Statistical Software*. The Test of Significance was done at 5% level.

Results and Discussion

Size of nuts

The length, breadth and thickness of raw cashew nuts (Table I and II) were respectively: 30.51, 23.84 and 16.50 mm for graded nuts; and 27.28, 17.81 and 11.45 mm for ungraded nuts at 6% moisture content and the size has been increased to 31.94, 24.42 and 18.38 mm for graded nuts; and 32.13, 21.91 and 14.13 mm for ungraded nuts at 10% moisture content. The length, width and thickness of graded samples were bigger compared to ungraded samples. The geometric mean diameter, sphericity and 100 nuts mass of graded raw cashew nuts were 23.22 mm, 0.92 and 549.8 g, respectively while the same parameters for ungraded nuts were 22.22 mm, 1.18 and 385.2 g, at 10% moisture content. The geometric mean diameter and sphericity of graded samples were higher compared to ungraded samples.

Shape

By visual observation, the cashew nut shapes were compared with the standard chart and the shape of the raw cashew nut was found to be kidney shape.

Gravimetric Properties

True density

The true density of graded cashew nut (Table III) was 1066.2 kg/m^3 at 6% moisture content that increased to 1107.3 kg/m^3 when the nut moisture content increased to 10%. Similarly, the true density values for ungraded cashew nuts (Table IV) were 934.6 kg/m^3 and 969.4 kg/m^3 at 6% and 10% moisture contents, respectively.

Bulk density

The bulk density of graded cashew nut was 613.6 kg/m^3 at 6% moisture content that decreased to 590.3 kg/m^3 when the nut moisture content increased to 10%. Similarly, the bulk density values for ungraded cashew nuts were 595.6 kg/m^3 and 568.6 kg/m^3 at 6% and 9% moisture contents, respectively.

Porosity

The porosity of graded cashew nut was 41.7% at 6% moisture content that increased to 46.7% when the nut moisture content increases to 10%. Similarly, porosity values for ungraded cashew nuts were 36.2% and 41.3 at 6 % and 10 % moisture contents, respectively.

Frictional properties

Angle of repose

The angle of repose of graded cashew nut (Table V) was respectively 23.9°, 26.8° and 28.6° at 6%, 8% and 10% moisture content. Similarly, the angle of repose values for ungraded cashew nuts (Table VI) were 20.9° and 24.4° at 6%, 8% and 10% moisture contents, respectively. The angle of repose values increased with increase in moisture content of cashew nuts.

Table I Physical Dimensions of graded cashew nuts

Dimension	Moisture Contents, % (w.b.)			S.Ed.	F	CV (%)	CD (0.05)
	6	8	10				
Length, mm	30.51±1.91	31.76 ± 1.11	31.94 ± 1.43	1.1768	0.8590 NS	4.64	2.8796
Width, mm	23.84±1.42	24.24 ± 1.34	24.42 ± 1.18	0.9730	0.1885 NS	4.90	2.3838
Thickness, mm	16.50±1.51	18.08 ± 0.75	18.38 ± 1.26	0.6603	4.6618 NS	4.98	1.6158
Geometric mean diameter (mm)	22.89 ± 1.61	23.07 ± 0.82	23.22 ± 0.91	0.8895	0.0663 NS	4.79	2.1757
Sphericity	0.75 ± 1.47	0.89 ± 0.57	0.92 ± 0.76	0.0346	13.9321 **	4.95	0.0848
100 nuts mass, g	488.67	528.25	549.84	15.3946	8.1221 *	3.61	37.6685

Table II Physical Dimensions of un-graded cashew nuts

Dimension	Moisture Contents, % (w.b.)			S.Ed.	F	CV (%)	CD (0.05)
	6	8	10				
Length, mm	27.28±4.58	29.51 ± 3.42	32.13 ± 3.17	1.126	9.3391 NS	4.64	2.7226
Width, mm	17.81±3.62	19.62 ± 2.15	21.91 ± 1.76	0.7999	13.391 **	4.92	1.9573
Thickness, mm	11.45±3.03	13.57 ± 2.19	14.13 ± 2.74	0.4911	16.5705 **	4.61	1.2018
Geometric mean diameter (mm)	17.72 ± 3.74	18.94 ± 3.08	22.22 ± 0.91	0.7624	18.1457 **	4.82	1.8055
Sphericity	0.64 ± 4.26	0.92 ± 3.14	1.18 ± 2.67	0.0377	102.562 NS	3.61	26.961
100 nuts mass, g	365.33	371.92	385.28	11.0183	1.7021 **	5.04	0.0923

Table III Gravimetric properties of graded cashew nuts

Treatments	Moisture Content (% wb)	True Density (kg/m^3)	Bulk Density (kg/m^3)	Porosity (%)
T1	6.0	1066.2	613.6	41.7
T2	8.0	1093.6	605.2	43.6
T3	10.0	1107.3	590.3	46.7
	S.Ed.	30.8051	21.4650	0.9515
	F	0.9232 NS	0.6044 NS	14.0728 **
	CV (%)	3.46	4.36	3.52
	CD (0.05)	75.3806	52.5254	2.3283

Table IV Gravimetric properties of un-graded cashew nuts

Treatments	Moisture Content (% wb)	True Density (kg/m^3)	Bulk Density (kg/m^3)	Porosity (%)
T1	6.0	934.6	595.6	36.2
T2	8.0	954.2	571.5	38.7
T3	10.0	969.4	568.6	41.3
	S.Ed.	26.9501	20.5955	0.8375
	F	0.8381 NS	1.0358 NS	18.54422 **
	CV (%)	3.46	4.36	2.65
	CD (0.05)	65.9474	50.3977	2.0495

Table V Frictional properties of graded cashew nuts

Treatments	Moisture Content (%, wb)	Coefficient of Friction	Angle of Repose
			Filling
T1	6.0	0.44	20.9
T2	8.0	0.47	22.5
T3	10.0	0.52	24.4
	S.Ed.	0.0136	0.8467
	F	17.8515 **	8.5634 *
	CV (%)	3.51	4.59
	CD (0.05)	0.0334	2.0719

Table VI Frictional properties of un-graded cashew nuts

Treatments	Moisture Content (%, wb)	Coefficient of Friction	Angle of Repose
			Filling
T1	6.0	0.55	23.9
T2	8.0	0.59	26.8
T3	10.0	0.63	28.6
	S.Ed.	0.0175	0.9913
	F	9.5711 **	11.4277 **
	CV (%)	3.63	4.59
	CD (0.05)	0.0429	2.4257

Co-efficient of static friction

The coefficient of friction of graded cashew nut was 0.55 at 6 % moisture content which however, increased to 0.63 when the nut moisture content increased to 10% and the friction value at 8% moisture content was 0.59. Similarly, the coefficient of friction values for ungraded cashew nuts were 0.44, 0.47 and 0.52 at 6, 8 and 10% moisture contents, respectively.

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