

Original Research Article

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Effect of Moisture Content on Engineering Properties of Cashew Nut

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ABSTRACT

Keywords

Cashew nut, Engineering properties, Moisture content

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Cashew nut is an important cash crop having a fair share of the export market. In this study, the effect of moisture content on engineering properties of cashew nuts was evaluated to facilitate the design of agricultural machinery. The linear dimensions and geometric mean diameter are used in design of seed handling and cleaning machinery. The average sphericity, bulk density, true density, porosity, shell thickness and static coefficient of friction determines the design of sieve separators, storage, separation devices, drying equipment, width of shelling blades and selection of fabrication material for the hopper, respectively. The properties viz. length, width, thickness, geometric mean diameter, surface area, volume and sphericity increased in the range of 27.12 to 28.54 mm, 21.27 to 22.59 mm, 15.06 to 16.65 mm, 20.53 to 22.04 mm, 1325.69 to 1527.86 mm² and 4695.41 to 5771.74 mm³ and 75.82 to 77.28%, respectively with increase in moisture content. The true density was higher in comparison to the bulk density. The decrease in porosity and angle of repose was observed with increase in moisture content. The coefficient of static friction of the seed was found to be highest in case of plywood with an average shell thickness of 2.48 mm.

Introduction

Cashew (*Anacardium occidentale*) is a tree fruit native to South and Central America. The tree produces seed commonly known as cashew nut. The kernel obtained from the cashew nut has a major contribution in the food industry and commonly consumed as snack in households. This seed comprises 40 to 57% oil and 21% protein (Ogunwolu *et al.*, 2009). The seed is covered with hard shell and has versatile industrial applications including production of paints and lubricants. The Cashew Nut Shell Liquid (CNSL)

excreted from the shell during the processing of cashew nut is a natural source of saturated and unsaturated long-chain phenol (Maia *et al.*, 2012) which can be used as antioxidants. India was the second largest exporter of shelled cashew nut after Western Africa with an export of 1, 98,000 tonnes (t) in 2019 (Statistical Yearbook, 2019).

It had the largest area of 1062.04 ha under cashew and imports about 6 to 7 lakh t of raw cashew nuts annually. Cashew nut industry had observed an increase in 70% of international price in the recent times. India is

a major cashew nut consuming country but a significant decline of ₹ 80 to 90 per kg in the price of raw cashew nut was observed due to depressed import duty on raw cashew nuts and higher cost of production (Cashew news, 2019).

Therefore, to mechanize the processes involved in production to consumption of the cashew nuts (includes design of sowing, harvesting, separation, roasting, shelling, peeling, grading, packaging and storage machinery) data about the engineering properties are required.

The basic dimensions of length, width and thickness are used in design of a cup for metering mechanism (Mohsenin, 1986) and seed handling machinery (Guiotto *et al.*, 2013; Omobuwajo *et al.*, 1999). The average sphericity of seed representing the same volume in a sphere (Omobuwajo *et al.*, 1999) for design of sieve separators. The Geometric mean diameter indicates particle behavior in a pneumatic medium and ease of separating unwanted materials throughout the cleaning process (Guiotto *et al.*, 2013), (Omobuwajo *et al.*, 1999). The bulk density, true density and porosity are important for the design of hopper storage, separation devices and drying equipment, respectively. The shell thickness was used to determine the width of shelling blades. For constant flow of seeds and selection of fabrication material of the hopper the average static coefficient of friction is required (Olajide and Igbeka, 2003).

The angle of repose facilitates the filling of the flat storage facility where the seeds are peaked (Mohsenin, 1986; Heidarbeigi *et al.*, 2009). Moisture content (mc) is an important factor considered in design and development of machineries for produce (Tabatabaefar, 2003). The major objective was to study the effect of moisture content on various engineering properties of cashew nuts.

Materials and Methods

Sample preparation

Raw cashew nuts (Variety: Vengurla-4) were collected from the factories of Mancachar, Assam, India. The moisture content of the sample was determined by oven drying method, as per ASAE standard, 1993 (Ojediran *et al.*, 2010; Seifi *et al.*, 2010; Sezer *et al.*, 2011). In oven drying method, the sample was kept in hot air oven at 105°C for 12 hours. The initial moisture content of the nuts was found to be 14%. The seed moisture content during the pre-shelling treatment using oven roasting method varied from 6 to 14%. Therefore, four levels of moisture content 14, 11, 9 and 6% (db) were selected for the analysis of the engineering properties. The seeds samples were conditioned by addition of calculated amount of distilled water in to achieve desired moisture content using equation (1) (Sologubik *et al.*, 2013; Solomon and Zewdu, 2009; Sacilinket *et al.*, 2003; Karababa, 2006; Altuntas and Yildiz, 2007; Singh *et al.*, 2010; Balasubramanian and Viswanathan, 2010). The seeds were refrigerated at 5 °C for five days to attain uniform moisture content. Prior to experimentation, the samples were kept in room temperature for 2 h (Balasubramanian and Viswanathan, 2010).

$$Q = \frac{B_i(M_f - M_i)}{M_i + 100} \quad (1)$$

where, B_i is initial mass of cashew nuts (kg); M_i and M_f are the initial and final moisture content of cashew nuts in % (db) and Q is the mass of water added (kg).

Properties determined

The basic dimensions of 100 roasted cashew nuts along the principal axes viz. length l (mm), width w (mm), and thickness t (mm) were measured using a digital Vernier caliper

of 0.005 mm accuracy. The geometric mean diameter G (mm), surface area A (mm^2), volume (V), and sphericity S (%) were determined using the following equation (2), (3) (4) and (5), respectively (Tabatabaefar, 2003; Mohsenin, 1986; Singh *et al.*, 2017) as shown below:

$$G = (lwt)^{\frac{1}{3}} \quad (2)$$

$$A = \pi(G)^2 \quad (3)$$

$$V = 0.25\left(\frac{\pi}{6} \times l(w + t)^2\right) \quad (4)$$

$$S = \frac{G}{L} \times 100\% \quad (5)$$

Thousand cashew nuts weight was measured by selecting 1000 nuts randomly and weighing it using an electronic balance of 0.001 g accuracy (Singh *et al.*, 2017).

A digital weighing balance of 0.001 g accuracy was used to measure the individual weight of cashew nuts. True density T (kg m^{-3}) is defined as the ratio of the weight of individual cashew nut M (kg) to the volume of toluene displaced V (m^3). The true density was evaluated using the toluene displacement method (Mohsenin, 1986; Dursun and Dursun, 2005; Singh *et al.*, 2017) expressed as:

$$T = \frac{M}{V} \quad (6)$$

Equation 7 was used to determine the bulk density B (kg m^{-3}) where m and v are the total weight of cashew nuts m (kg) and the volume of cylinder v (m^3) respectively (Chandrasekhar and Viswanathan, 1999; Singh *et al.*, 2017).

$$B = \frac{m}{v} \quad (7)$$

The porosity P (%) was calculated using the measured values of bulk density and true density by using the equation (8) (Mohsenin, 1986; Balasubramanian and Viswanathan,

2010; Singh *et al.*, 2017)

$$P = \frac{T-B}{T} \times 100\% \quad (8)$$

The angle of repose was evaluated using the emptying method by measuring the depth d (mm) and height h (mm) of the heap formed naturally as a result of the gradual raising of the cylinder.

$$\theta = \tan^{-1}\left(\frac{2h}{d}\right) \quad (9)$$

The coefficients of static friction on four material surfaces mild steel (μ_m), aluminum (μ_a), galvanized iron (μ_g) and plywood (μ_p) was determined by using tilting table method (Fraser *et al.*, 1978) calculated by equation (10) (Fig. 2) (Sahay and Singh, 2009; Khan, *et al.*, 2017).

$$\mu = \tan \theta \quad (10)$$

The shell thickness S_T (mm) was measured using a digital micrometer of 0.01 mm accuracy at three points viz. top, middle and bottom of the cashew nut.

Results and Discussion

Engineering properties of cashew nuts were measured at moisture content level of 6, 9, 11, 14% (db) within the moisture range of 6 to 14% (db).

Length

The length of cashew nuts [Fig. 1(a)] increased gradually from 27.12 to 28.54 mm as the moisture content increased from 6 to 14% (db) (Fig. 3). Similar increasing trend was observed by Gharib-Zahedi *et al.*, 2010, Seifi and Alimardani, 2010, and Sologubik, *et al.*, 2013, for black cumin seeds, corn and barley seeds respectively.

Width

The width of the cashew nuts [Fig. 1(b)] increased in the range of 21.27 to 22.59 mm with increase in moisture content as shown in Fig. 4. Similar increasing trend was observed for black cumin seeds (Gharib-Zahedi *et al.*, 2010) and corn (Seifi and Alimardani, 2010).

Thickness

The thickness of the cashew nuts [Fig. 1(c)] was found to have increased with increase in moisture content. With increase in moisture content from 6 to 14% (db) the seed thickness increased from 15.06 to 16.65 mm as shown in Fig. 5. Similar increasing trend was observed for black cumin seed (Gharib-Zahedi *et al.*,

2010), corn (Seifi and Alimardani, 2010) and barley seeds (Sologubik, *et al.*, 2013).

Geometric mean diameter

The geometric mean diameter was calculated by using the linear dimensions as specified in equation 2. The geometric mean diameter was observed to be increasing linearly from 6-11% mc but increased gradually thereafter (Fig. 6). Similar increasing trend was observed by Shafiee *et al.*, (2009) for dragon's head seeds, Singh *et al.*, (2010) for millet and Sologubik, *et al.*, (2013) for barley seeds.

Fig.1 Basic dimensions of cashew nut (a) Length (L), (b) Width (W), (c) Thickness (T)

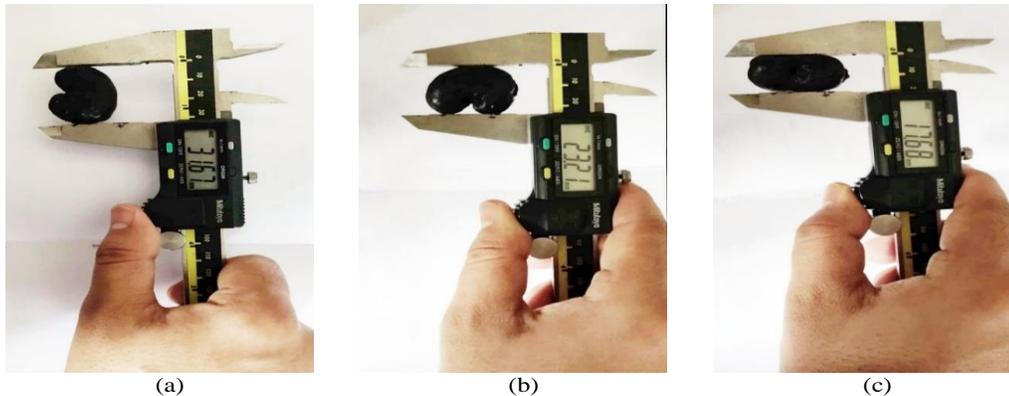


Fig.2 Tilting-top table apparatus for measurement of coefficient of static friction



Fig.3 Effect of moisture content on length of the cashew nut

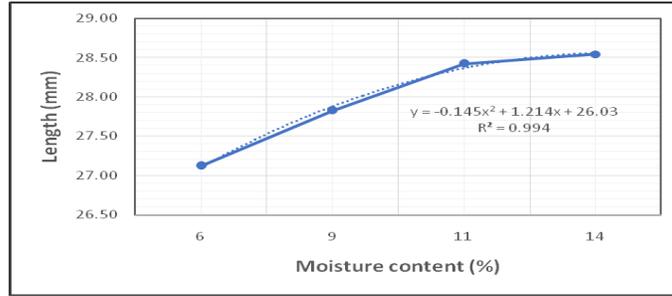


Fig.4 Effect of moisture content on width of the cashew nut

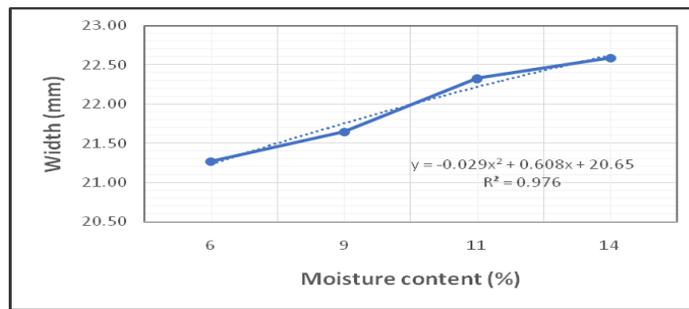


Fig.5 Effect of moisture content on thickness of the cashew nut

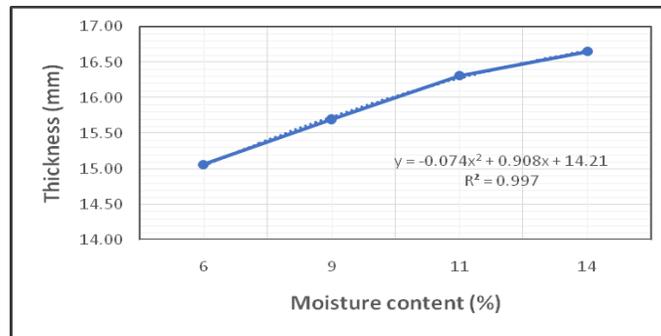


Fig.6 Effect of moisture content on geometric mean diameter of the cashew nut

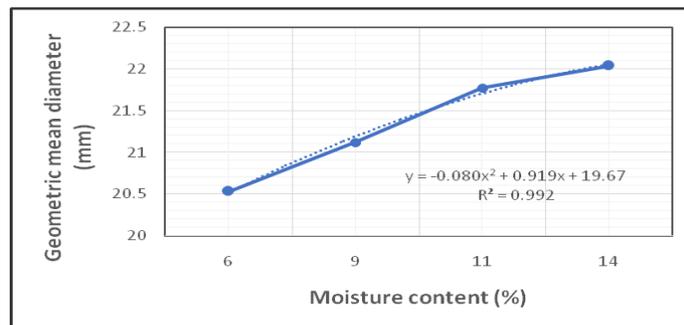


Fig.7 Effect of moisture content on surface area of the cashew nut

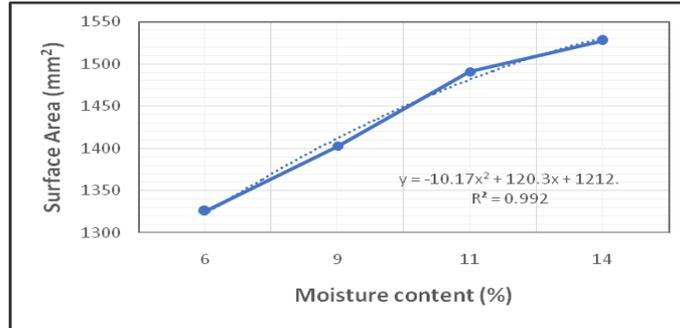


Fig.8 Effect of moisture content on volume of the cashew nut

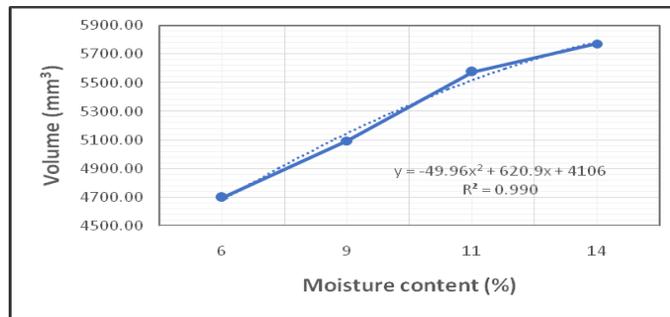


Fig.9 Effect of moisture content on sphericity of the cashew nut

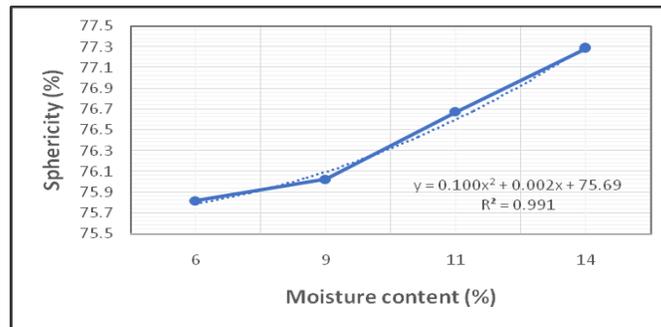


Fig.10 Effect of moisture content on thousand cashew nuts weight

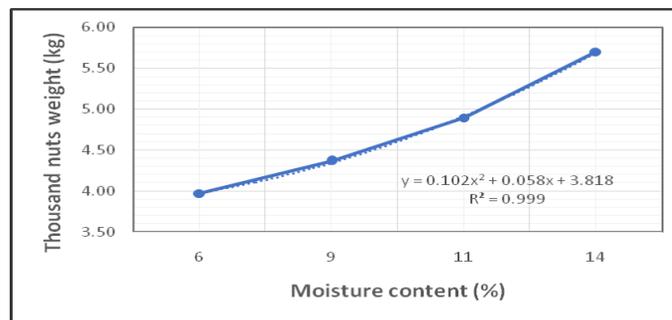


Fig.11 Effect of moisture content on true density of the cashew nut

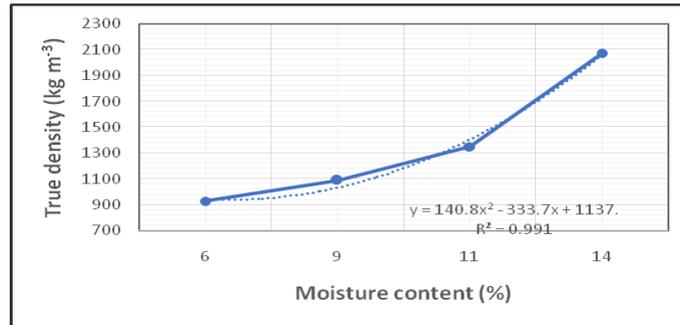


Fig.12 Effect of moisture content on bulk density of the cashew nut

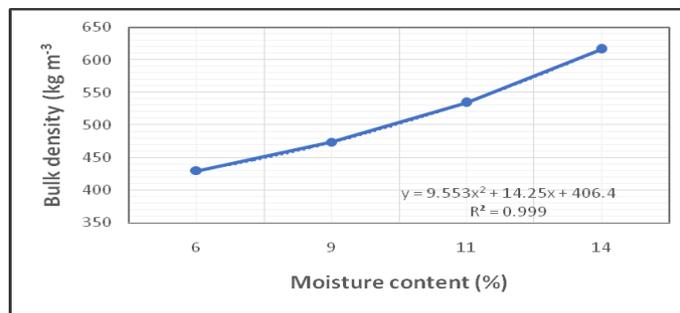


Fig.13 Effect of moisture content on porosity of the cashew nut

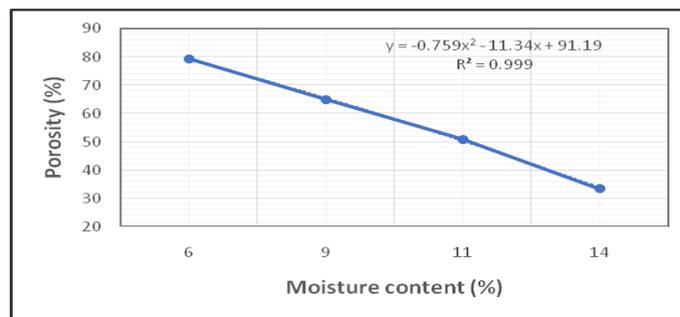


Fig.14 Effect of moisture content on angle of repose of the cashew nut

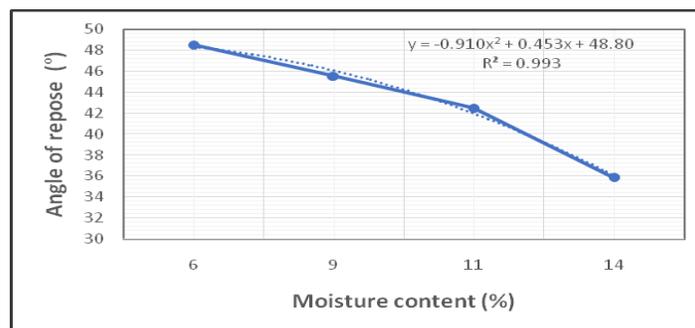
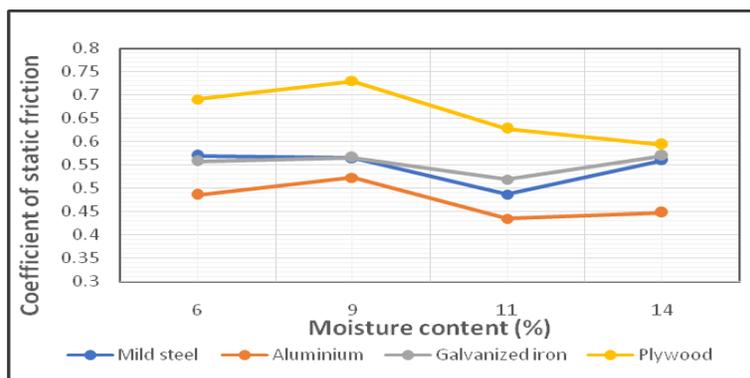


Fig.15 Effect of moisture content on coefficient of static friction of the cashew nut

Surface area

The surface area was calculated by using the linear dimensions as specified in equation 3. The surface area was observed to be increasing linearly from 6-11% mc but increased steadily thereafter (Fig. 7). Similar increasing trend was observed by Shafiee *et al.*, 2009 for dragon's head seeds, Singh *et al.*, 2010 for millet and Sologubik, *et al.*, 2013 for barley seeds.

Volume

The volume of cashew nuts was calculated by using equation 4. The volume was observed to be increasing linearly from 6-11% mc but increased steadily thereafter (Fig. 8). Similar increasing trend was observed by Singh, *et al.*, 2017, for finger millet.

Sphericity

The sphericity was calculated by using geometric mean diameter and the length of the seeds (equation 5). The sphericity increased gradually from 75.82 to 77.28% with increase in moisture content from 6 to 14% (db) (Fig. 9). Similar trend was observed by Shafiee *et al.*, 2009 for dragon's head seeds, Singh *et al.*, 2010 for millet, Sologubik, *et al.*, 2013 for barley seeds and Singh, *et al.*, 2017 for finger millet.

Thousand cashew nuts weight

The thousand cashew nuts weight (W_{1000}) was determined for the concerned levels of moisture content as shown in Fig. 10. The thousand seed weight increased within the range of 3.97 to 5.70 kg with increase in moisture content from 6 to 14% (db). Similar increase in seed weight was observed by Shafiee *et al.*, (2009) for dragon's head seeds and Singh, *et al.*, (2017) for finger millet.

True density

The true density trend to increase with increase of moisture content. The true density varied within the range of 926.83 to 2075.00 kg m^{-3} with moisture content ranging from 6 to 14% (db) (Fig. 11). Since, true density is directly proportional to mass, this explains the increase in moisture content increased the mass of the cashew nuts. Shafiee *et al.*, 2009, Singh *et al.*, 2010 and Singh, *et al.*, 2017 reported similar results for dragon's head seed, barnyard millet and finger millet respectively.

Bulk density

The bulk density trend to increase with increase of moisture content. The bulk density varied within the range 429.96 to 616.55 kg m^{-3} with moisture content ranging from 6 to

14% (db) (Fig. 12). Similar linear trend was reported by Aviara *et al.*, 1999 for guna seeds.

Porosity

The porosity trend to decrease with increase of moisture content from 6-14% (db). The porosity varied from 79.28 to 33.48% with moisture content ranging from 6 to 14% (db) (Fig. 13). The decrease in porosity occurs as the individual volume of the seed increases due to the absorption of moisture. Similar behavior was reported by Mwithiga and Sifuna, 2006 for sorghum seeds.

Angle of repose

The angle of repose decreased significantly from 35.87° to 48.51° with increase in moisture content from 6 to 14% (db) (Fig. 14). This is because seed surface smoothens at higher moisture content in comparison to dry seeds. Similar behavior was reported by Mwithiga and Sifuna, 2006 for sorghum seeds.

Coefficients of static friction

The coefficient of static friction of cashew nuts was determined by using four surfaces (Fig. 2) (mild steel, aluminium, galvanized iron and plywood) at 6, 9, 11, and 14% moisture content (Fig. 15). The coefficient of static friction for mild steel, aluminium, galvanized iron and plywood was in the range of 0.49 to 0.57, 0.44 to 0.52, 0.52 to 0.57, 0.59 to 0.73, respectively.

Shell thickness

The shell thickness of the cashew nut was found to be in the range of 1.97 to 3.12 mm with an average value of 2.48 mm. The shell thickness remains the same in contrast to variation in moisture content.

In conclusion it is evident from the results of the study that most of the parameter values (i.e., length, width thickness, GMD, surface area, volume, sphericity, W_{1000} , true density and bulk density) increased with increase in moisture content from 6% to 14%. However, the values of porosity and angle of repose decreased with increase in moisture content in the same range. No specific trend was noticed for the coefficient of static friction. The results would be helpful in designing various components of machines for post-harvest processing of cashew nut.

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