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Moisture-dependent physical properties of groundnut pods and kernels of TMV 2 variety

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Abstract
Some physical properties of groundnut pod and kernel of variety TMV2, widely cultivated in Odisha, India, were evaluated as a function of moisture content. The physical properties were studied as dependent variables and moisture content as independent variable. The different moisture contents during the study were 8.68, 9.57, 11.31, 14.46, 18.47, 20.08 and 22.39% (d.b) for the pod and 10.98, 13.57, 16.31, 20.46, 22.47, 23.08 and 24.39% (d.b.) for the kernels. The results revealed that at an increasing moisture content 8.68-22.39% (d.b.) for pods, the average length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity, surface area, bulk density, true density, porosity, 1000-unit mass, angle of repose and crushing strength were respectively 24.32-27.42 mm, 11.13-13.08 mm, 11.54-13.74 mm, 15.67-18.08 mm, 14.54-17.01 mm, 0.59-0.629, 668.15-818.23 mm^2, 255.12-150.98 kg/m^3, 470.53-810.56 kg/m^3, 44.36-81.37%, 798.23-1053.35 g, 39.61-43.01 degrees and 11.23-8.07 N. Similarly, for the kernels at an increasing moisture contents 10.98-24.39% (d.b.), the corresponding values were respectively 10.32-10.67 mm, 6.84-7.93 mm, 6.72-7.57 mm, 7.96-8.72 mm, 7.79-8.62 mm, 0.75-0.80, 187.43-201.24 mm^2, 547.65-477.86 kg/m^3, 950.56-1062.89 kg/m^3, 42.38-55.04%, 294.89-546.78 g, 30.99-38.12 degrees and 7.23-4.45 N. The mean static coefficient of friction on GI sheet, plywood and plastic sheet increased at increasing moisture content for both pods and kernels. Information obtained through the experiments would not only be the useful data for engineer in designing planting and post-harvest equipment of groundnut but also for food scientists, food processor and plant breeders.

Keywords: Groundnut, physical properties, oil seed, moisture content, TMV2 variety groundnut

Introduction
Groundnut is a major oil seed crop cultivated in the state of Odisha (17^0 31′ N to 20^0 31′ N latitude and 81^0 31′ E to 87^0 30′ E longitude) where climate is most suitable for groundnut cultivation during Kharif and Rabi season (Anonymous 2015) [1]. It contributes a major share to oil seed production of the state. The commercial importance of the groundnut crop has been increasing since time immemorial, because of its utility as edible oil and as raw material for some industries to manufacture soaps, hair oils, lubricants, paints, medical ointments and creams etc. About 80% of the total groundnut produced undergoes processing for getting edible oil and oil cake. Considering groundnut as a major contributor for oil industry at the national level and requirement of good quality seeds for cultivation purposes at the farmers' level, mechanization of its post-harvest operations plays an important role for getting better output and remunerative price from the crop. From harvesting to processing, groundnut passes through several ranges of moisture content till the end product is obtained. The widely cultivated variety of groundnut in the state is TMV2 which is a bunchy variety, growing period of 105-110 days, grows in sandy loam and loam sand soil and mostly spheroidal in shape. For handling and processing of the groundnut, some equipment are available commercially, but these are developed without following the relevant physical properties of that variety resulting into their poor performance causing low quality of the products. The commercially available one power (1 hp) operated cast iron sheller bar type groundnut decorticator in the state showed low shelling efficiency and high kernel breakages (Paritosh and Ghosal, 2016) [32]. Properties related to design of groundnut handling equipment were investigated by various researchers. However, in most of the cases, the physical properties have been investigated at fixed moisture content.

Olajide and Igbeka 2003 [24], studied the physical properties of groundnut pod at 4.6% moisture content, Dilmac and Altuntas, 2012 [11] for peanut pod and kernel at moisture content of 8.25% and 10.03% respectively, Fashina *et al*., 2014 [12] for Samnut 10, Samnut 14 and Samnut 18 at 8% moisture content. Alam *et al*., (2013) [3] emphasized on the need to investigate some engineering properties of groundnut as affected by the changes in the moisture contents. The knowledge would be used in designing of appropriate planting and harvesting machinery and equipment for pneumatic conveying, separating, shelling, drying and storage of the product. The present study is thus undertaken to find out the engineering/physical properties of the pod and kernel of TMV 2 variety groundnut as a function of moisture contents with a view to redesign and improvement of commonly cultivated local groundnut handling equipment. This has become necessary looking into the prevalent low-quality kernels from groundnut processing clusters which poses risk of kernel contaminations.

Materials and Methods

Sample

The groundnut pod was procured from State Seed Corporation, Odisha, Bhubaneswar for the study. The study was conducted in Odisha University of Agriculture and Technology. The sample was selected, cleaned manually and pooled together to obtain approximately 10 kg of pods. It was ensured that the pods were free of dirt, broken ones, immature pods and other foreign materials. The pods were kept in the room conditions (27-32 ^{0}C, 75-80% RH) for two days to obtain the equilibrium moisture. The pods were decorticated carefully and manually to get the whole kernel. The shells and kernels were separated manually for analysis.

Determination of moisture content

The moisture content of the pod and kernel were determined separately using American Society of Agricultural Engineers (ASAE) standard method (ASAE, 1989) [6]. Weighed amount of the samples were dried in a hot air oven at 105 ± 2 ^{0}C and weighed every time after cooling the samples in desiccator till constant weight was obtained. Weight loss on drying to a final constant weight was recorded as moisture content of the material. The moisture content (dry basis) of the pod and kernel was calculated using the following equation,

Moisture content (%) = [(Initial weight of sample-final weight of sample) / (dry weight of sample)] x 100.

The initial moisture contents of pod and kernel were respectively 8.68% d.b. and 10.98% d.b.

Samples were moistened with a calculated quantity of water by using the following Eq. (1). and conditioned to raise their moisture content to the seven different levels (Cos¸kun *et al*., 2005) [8].

$$Q = W_i (M_f - M_i)/ (100 - M_f) \qquad (1)$$

where Q is the mass of water added, kg, W_i is the initial mass of the sample in kg, M_i is the initial moisture content of the sample in d.b.% and M_f is the final moisture content of the sample in d.b.%. A pre-determined quantity of tap water was added to the kernel sub-lot of 2.5 kg and was thoroughly mixed. These rewetted samples were then poured in high density polyethylene bags of 100-microns thickness and the bags were sealed tightly. The samples were kept at 5 ^{0}C in a refrigerator for a week to enable the moisture to distribute uniformly throughout the sample. Before starting the tests, the required quantities of the samples were taken out of the refrigerator and allowed to warm to room temperature for about 2 h. All the physical properties of the pod and kernel were assessed at moisture levels of 8.68, 9.57, 11.31, 14.46, 18.47, 20.08 and 22.39% (d.b). and 10.98, 13.57, 16.31, 20.46, 22.47, 23.08 and 24.39% (d.b.) respectively. The rewetting technique to attain the desired moisture content in kernel and grain has frequently been used (Nimkar and Chattopadhyay, 2001; Sacilik *et al*., 2003; Cos¸ kun *et al*., 2005; Garnayak *et al*., 2008) [21, 28, 18, 14].

Physical Characteristics of Pod and Kernel

The pod and kernel materials were divided into 5 lots each and 20 samples were selected at random from each lot of pod and kernel to obtain 100 samples each for conducting the experiments.

Physical Dimensions

The physical dimensions are the length, equatorial diameter (width) and breadth (thickness). The length (L) refers to the major diameter while the breadth (T) is the minor diameter of the pod/kernel. The intermediate diameter is the equatorial diameter or width (W). Knowledge of these dimensions is useful in determining aperture sizes in the design of pod/kernel handling equipment (Omobuwajo *et al*., 1999) [25].

The length (L), width (W) and thickness (T) of groundnut pod were measured using a vernier slide caliper with an accurate reading of 0.02 mm. The average diameter was calculated by using the arithmetic mean and geometer mean of the three axial dimensions. The arithmetic mean diameter, D_a, and geometric mean diameter, D_g, of the groundnut pod and kernel were calculated by using the following relationships (Dash *et al*., 2008 and Davies 2009) [9, 10].

$$D_a = (L+W+T) / (3) \text{ and } D_g = (LWT)^{1/3}$$

Thousand-unit weight determination

A 1000-unit mass refers to the mass of thousand pods/kernels. The mass and density characteristics of the pods are quite useful in estimating product yield and machine throughput of equipment (Omobuwajo *et al*., 1999) [25]. Pod weight affects pod flow and in turn, influences the design of hoppers for pods in processing equipment (Jayan and Kumar, 2004) [16]. One-thousand-unit weight was determined by means of a digital electronic balance having an accuracy of 0.001 g. To evaluate the 1000-unit weight, 20 randomly selected pods from each moisture level were averaged.

Sphericity

The flowability characteristic of the pod and kernel is influenced by the sphericity, such that movement of non-spherical seeds under gravity is mostly slow (Omobuwajo *et al*., 1999; Jayan and Kumar, 2004) [25, 16]. The sphericity of groundnut pod/kernel was calculated by using the following relationship (Mohsenin, 1986) [20].

$$\Phi = (LWT)^{1/3}/(L)$$

Aspect ratio

The aspect ratio, R_a was calculated by applying the following relationships given by (Maduako *et al* 2006 and Ogunjimi *et al* 2002) [19, 23].

$R_a = (W/L) \times 100$

Surface area

The surface area was determined by coating the surface of the pod with aluminum foil. The surface edge of the aluminum foil was traced out with a very sharp thin pencil on a graph paper. The surface area was measured by counting the number of squares within the traced marks (Adejumo and Abayomi 2012) [2].

Bulk density

Bulk density is the density of the material when packed or stacked in bulk while solid density is the density of the material excluding any interior pores that are filled with air (Sahin and Sumnu, 2006) [31]. Materials with large pore spaces among them have lower bulk densities compared with those having small pore spaces. The bulk density was determined by filling a cylindrical container of 500 ml volume with the pod/kernel from a height of 150 mm at a constant rate and then weighing the contents (Gupta and Das, 1997; Garnayak *et al*., 2008) [15, 14]. No separate manual compaction of pods/kernels was done. The bulk density was calculated from the mass of the bulk material divided by the volume containing the mass.

True density

The true density is defined as the ratio between the weight of groundnut pod/kernel to the true volume of the pod/kernel, determined using the toluene (C_7H_8) displacement method. Toluene was used in place of water, because, it is absorbed by pods to a lesser extent. The volume of toluene displaced was found by immersing a weighted quantity of pod/kernel in the measured toluene (Sacilik *et al*., 2003; Garnayak *et al*., 2008) [28, 14].

Porosity

Porosity is usually needed in air flow and heat flow situations like winnowing, cleaning, drying, storage, etc. (Garnayak *et al*., 2008; Pradhan *et al*., 2009) [14, 27]. According to Mohsenin (1986) [26], porosity (%) is the parameter indicating the amount of pores in the bulk materials. It is calculated from the bulk and true density using the following equation. $\epsilon\ (\%) = [(\rho_t - \rho_b)/\rho_t] \times 100$; where ρ_b = Bulk density; ρ_t = True density

Angle of repose

Angle of repose is also a very important physical property of pod/kernel, useful for the design of processing, storage and conveying systems of agricultural materials. When the grains or seeds are smooth and rounded, the angle of repose is low. Very fine and sticky materials have high angle of repose due to high friction among them (Sahin and Sumnu, 2006; Sirisomboon *et al*., 2007) [31, 34].

The arrangement for determining the angle of repose for the present study consists of a square box of side 84 mm and height 80 mm (Paritosh 2013) [33]. It consists of a circular platform of diameter 80 mm inside it. An opening is made at the bottom of the box, below the circular platform to allow for the free fall of pod/kernel. The whole unit was placed at a height of 300 mm. One wall of the box is transparent and it consists of a scale fixed vertically keeping it leveled to the circular platform. Its opposite wall is a mirror so that we can see the pile formed on the platform and take the observations from the mirror avoiding parallax. In the beginning, the box was filled with the pods/kernels keeping the bottom closed. Then, on opening the bottom, the pods/kernels were allowed to fall freely. They formed a pile on the circular platform and the height of the pile was taken by the scale from the image formed at the mirror. This process was repeated for twenty times and using the equation (Karababa 2006) [17] i.e. $\tan\theta = 2H/D$; where H = Height of pile (cone) formed and D = Diameter of formed pile (cone), the angle of repose θ was calculated.

Coefficient of static friction

The coefficient of static friction for any biological material is determined by the force capable to initiate the movement. It depends on the type and nature of the materials or surfaces in contact. The data on coefficient of friction are important for hoppers and conveying units used in the decorticator. Static coefficient of friction of the pod/kernel was determined with respect to galvanized iron (GI) sheet, plastic and plywood, available easily and cheaply. A four sided plywood container with dimensions of 200 mm × 80 mm × 50 mm open at both the top and bottom was filled with the pods/kernels and placed on a plane surface of galvanized iron sheet, plastic and plywood separately for the experiments (Paritosh 2013) [33]. The whole structure was placed on a frame of height 1 meter from the ground. A pulley is set at the middle edge of the set-up. A thread hooked to the box is provided with the weighing plate. The box slides on a plane surface and weighing plate is allowed to hang down by means of a thread moving over the pulley. The box was at the beginning kept at the center position aligning with the pulley so that the box- pulley can be in a straight line. Then, the box was filled with pods/kernels keeping the other end weightless. Weights were added until the box filled with pods/kernel started to slide. Weight of box along with pod/kernel and weight used to make it slide, were calculated. Coefficient of static friction can be determined from, $\mu = F/N$; where F is the applied force and N is the normal load or force.

Crushing strength

Crushing strength of pod and kernel was measured by the application of forces with the help of Universal testing machine, available in the Department. The sample was placed on the stationary lower platform and press with the moving platform. The probe used in the experiment had a 20 mm diameter and was connected to the computer. The experiment was conducted at a loading velocity at 2 mm min^{-1}. The compressive force corresponding to the crushing of the pod and kernel was taken as the crushing strength of the sample.

Results and Discussion

Evaluation of physical properties

The average values of determined physical parameters of pod are shown from Tables 1-3 and for kernel from Tables 4-6. From the table, it is seen that the length ranging from 24.32-27.42 mm, width ranging from 11.13-13.08 mm and thickness ranging from 11.54-13.74 mm for the pods at moisture contents of between 8.68-22.39% (d.b.). Similarly, for the kernels, the length ranging from 10.32-10.69 mm, width ranging from 6.84-7.93 mm and thickness ranging from 6.72-7.57 mm at moisture contents of between 10.98-24.39% (d.b.). the results were similar to that reported by Payman *et al*., 2011 [26] and Firouzi, 2009 [13]. Each principal dimension was found to be in the increasing trend both for pods and kernels with increase of moisture contents. The increase is due to the swelling of the materials with the absorption of moisture.

The arithmetic mean diameter, geometric mean diameter, sphericity and surface area of both pods and kernels also increased with the increase in moisture content (Tables-1 and 4). These properties are dependent on the three linear dimensions, which were observed to increase with increase in moisture content. This may be attributed due to the fact that these properties depend on the three linear dimensions, which increase with increase in moisture content. Similar result was reported by Odesanya *et al*., 2015 [22] and Aydin 2007 [7]. These properties are very important in the selection of concave size for designing of shelling and separation equipment. The thousand mass of the sample i.e. pod increased from 798.23 to 1053.35 g with the same changes of moisture content from 8.68 to 22.39% (d.b.) and for kernel from 294.89 to 546.78 g with the moisture contents ranging from 10.98 to 24.39% (d.b.). a similar increasing trend has been reported for other seeds such as neem, jatropha, faba bean grains etc. (Altuntas and Demirtola, 2007, Kasap and Altuntas 2006) [4, 18].

The bulk density of pod and kernel decreased with the increase of moisture content. But true density and porosity increased with the increase of moisture content as presented in Tables 2 and 5. The decrease of bulk density was due to the fact that an increase in mass owing to moisture gain in the sample was lower than accompanying volumetric expansion of the bulk. If the increase of moisture content results in more increase in sample volume than mass, bulk density has the negative trend. However, in case of adverse result, the bulk density has a positive relationship with respect to the moisture content. A similar decreasing trend in bulk density has been reported by Altuntas and Demirtola, 2007 [4] for some legume seeds. The increase in true density varies with increase in moisture content might be attributed to the relatively lower true volume as compared to the corresponding mass of the sample attained due to the absorption of water. The porosity was evaluated using mean values of bulk density and true density. The porosity was also found to increase with the increase in the specified moisture levels both for pods and kernels. The densities values are used in design of storage bins and silos, separation of desirable materials from impurities, cleaning and grading and quality evaluation of the products. The porosity values are often needed in air flow and heat flow studies. The findings in the values of porosity for pods as well as kernels were in conformity with what was reported by Aydin, 2007 and Payman *et al*., 2011 [7, 26].

The angle of repose is an indicator of the product's ability to flow. The experimental results for the angle of repose with respect to moisture content for pods and kernels are shown in Tables 3 and 6 respectively. The values were found to increase with the increase in the specified moisture contents. This increasing trend of angle of repose with moisture content occurs because surface layer of moisture surrounding the particle hold the aggregate of the sample together by surface tension. These results were similar to those reported for neem nut, hemp seed, jatropha seed (Visvanathan *et al*., 1996, Kasap and Altuntas, 2006, Garnayak *et al*., 2008) [35, 18, 14].

The values of the static coefficient of friction of pod and kernels on three surfaces (GI sheet, plywood and plastic sheet) against the specified range of moisture contents under study are presented respectively in Tables 3 and 6. It was observed that the static coefficient of frictions were found to increase with the increase of moisture content for the three surfaces under study. The values were highest in case of GI sheet followed by the plywood and lowest for plastic sheet. The increasing trend may be due to the water present in the sample offering a adhesive force on the surface of contact causing decrease in sliding characteristics. The least static coefficient friction may be due to the smoother and more polished surface of the plastic sheet compared to the other materials used. The information regarding static coefficient of friction is necessary for designing of storage bins, hoppers, pneumatic conveying system, thresher, decorticator etc. (Sahay and Singh, 1996) [29]. This trend was in agreement with many researchers (Aydin 2007, Firouzi 2009, Payman *et al*., 2011) [7, 13, 26].

The values of crushing strength of pod and kernels against the specified range of moisture contents under study are also presented respectively in Tables 3 and 6. It was observed that the crushing strengths were found to decrease with the increase of moisture content. A similar decreasing trend in crushing strength has been reported for neem nut (Visvanathan *et al*., 1996) [35]. The decrease in crushing strength may be due to the sample becoming softer at higher moisture contents.

Table 1: Average geometric properties of pod (Number of samples = 100)

Moisture content (% d.b.)	Length (L) mm	Width (W) mm	Thickness (T) mm	Arithmetic mean diameter (mm)	Geometric mean diameter (mm)	Sphericity (decimal)	Surface area (mm^2)
8.68	24.32 (2.21)	11.13 (0.63)	11.54 (1.04)	15.67 (2.32)	14.54 (3.42)	0.59 (0.93)	668.15 (88.10)
9.57	24.83 (3.95)	11.56 (1.56)	11.96 (2.11)	16.11 (3.33)	15.08 (2.44)	0.60 (0.83)	691.43 (102.10)
11.31	25.12 (4.23)	11.92 (2.11)	12.25 (1.89)	16.43 (3.92)	15.42 (4.22)	0.61 (0.54)	720.65 (68.10)
14.46	25.56 (3.77)	12.43 (3.12)	12.94 (2.13)	16.98 (2.12)	16.01 (3.12)	0.62 (1.33)	778.73 (123.10)
18.47	26.26 (4.11)	12.78 (2.48)	13.23 (1.43)	17.42 (1.72)	16.43 (1.88)	0.625 (0.42)	796.82 (67.10)
20.08	26.88 (5.35)	12.98 (3.65)	13.54 (2.33)	17.80 (0.89)	16.77 (2.92)	0.628 (0.89)	802.9 (89.10)
22.39	27.42 (3.08)	13.08 (2.56)	13.74 (1.55)	18.08 (3.32)	17.01 (3.84)	0.629 (1.04)	818.23 (106.10)

(Standard deviation in parenthesis)

Table 2: Average gravimetric properties of pod (Number of samples = 100)

Moisture content (% d.b.)	Bulk density (kg/m^3)	True density (kg/m^3)	Porosity (%)	1000 unit mass (g)
8.68	255.12 (10.40)	470.53 (78.96)	44.36 (3.62)	798.23 (9.12)
9.57	234.45 (6.75)	520.67 (49.96)	54.97 (1.88)	830.98 (5.35)
11.31	212.89 (9.68)	595.78 (102.96)	64.26 (2.67)	876.78 (11.34)
14.46	189.57 (1.56)	667.64 (57.96)	71.60 (1.76)	897.64 (7.33)
18.47	176.93 (8.76)	735.98 (84.96)	75.95 (3.54)	940.65 (9.78)
20.08	162.89 (5.89)	789.45 (35.96)	79.36 (0.87)	990.65 (10.68)
22.39	150.98 (11.67)	810.56 (45.96)	81.37 (1.89)	1053.35 (6.98)

(Standard deviation in parenthesis)

Table 3: Average frictional properties of pod (Number of samples = 100)

Moisture content (% d.b.)	Angle of repose (degree)	Coefficient of static friction (decimal)			Crushing strength (N)
		GI sheet	Plywood	Plastic	
8.68	39.61 (3.83)	0.44 (0.03)	0.32 (0.01)	0.23 (0.04)	11.23 (2.34)
9.57	40.04 (2.21)	0.46 (0.02)	0.33 (0.04)	0.24 (1.12)	10.67 (0.54)
11.31	41.67 (1.45)	0.47 (0.06)	0.36 (0.05)	0.26 (0.08)	10.09 (1.14)
14.46	42.07 (0.85)	0.51 (0.05)	0.37 (0.02)	0.27 (0.05)	9.86 (0.67)
18.47	42.67 (0.64)	0.54 (1.11)	0.39 (0.09)	0.28 (1.01)	8.56 (0.87)
20.08	43.01 (1.23)	0.56 (0.03)	0.40 (0.08)	0.29 (0.09)	8.07 (1.03)
22.39	43.21(3.11)	0.57 (0.09)	0.41 (1.01)	0.30 (0.01)	7.45 (0.53)

(Standard deviation in parenthesis)

Table 4: Average geometric properties of kernel (Number of samples = 100)

Moisture content (% d.b.)	Length (L) mm	Width (W) mm	Thickness (T) mm	Arithmetic mean diameter (mm)	Geometric mean diameter (mm)	Sphericity (decimal)	Surface area (mm^2)
10.98	10.32 (1.09)	6.84 (0.91)	6.72 (1.12)	7.96 (0.54)	7.79 (0.53)	0.75 (0.11)	187.43 (25.10)
13.57	10.38 (2.01)	6.95 (0.75)	6.91 (2.17)	8.08 (0.87)	7.92 (0.85)	0.76 (0.34)	191.07 (17.45)
16.31	10.46 (1.46)	7.03 (0.89)	7.07 (0.98)	8.18 (1.09)	8.04 (1.09)	0.768 (0.56)	197.03 (40.56)
20.46	10.53 (0.98)	7.15 (0.67)	7.24 (1.25)	8.30 (1.26)	8.16 (0.45)	0.77 (0.87)	201.11 (22.98)
22.47	10.61 (0.57)	7.42 (1.06)	7.41 (1.37)	8.48 (0.98)	8.35 (0.79)	0.78 (0.23)	204.31 (15.34)
23.08	10.63 (1.05)	7.67 (1.56)	7.50 (0.67)	8.6 (1.04)	8.48 (1.23)	0.79 (0.67)	206.33 (11.56)
24.39	10.67 (2.15)	7.93 (0.67)	7.57 (1.56)	8.72 (0.67)	8.62 (0.89)	0.80 (0.96)	207.24 (34.23)

(Standard deviation in parenthesis)

Table 5: Average gravimetric properties of kernel (Number of samples = 100)

Moisture content (% d.b.)	Bulk density (kg/m^3)	True density (kg/m^3)	Porosity (%)	1000 unit mass (g)
10.98	547.65 (9.57)	950.56 (23.87)	42.38 (1.22)	294.89 (6.44)
13.57	533.67 (3.55)	972.34 (15.87)	45.11 (2.01)	329.07 (4.65)
16.31	518.98 (2.47)	995.43 (20.68)	47.86 (0.78)	378.76 (5.67)
20.46	505.34 (10.35)	1012.87 (24,98)	50.10 (1.54)	412.54 (0.98)
22.47	489.17 (11.05)	1030.96 (12.34)	52.55 (0.93)	469.87 (8.12)
23.08	482.33 (4.76)	1046.77 (23.74)	53.92 (1.23)	500.76 (6.31)
24.39	477.86 (8,98)	1062.89 (17,63)	55.04 (2.15)	546.78 (2.65)

(Standard deviation in parenthesis)

Table 6: Average frictional properties of kernel (Number of samples = 100)

Moisture content (% d.b.)	Angle of repose (degree)	Coefficient of static friction (decimal)			Crushing strength (N)
		GI sheet	Plywood	Plastic	
10.98	30.99 (3.01)	0.47 (0.04)	0.36 (0.05)	0.27 (0.01)	7.23 (1.44)
13.57	31.95 (2.69)	0.49 (0.01)	0.39 (0.01)	0.29 (0.02)	7.04 (0.89)
16.31	32.45 (1.89)	0.52 (1.02)	0.40 (0.03)	0.30 (1.05)	6.87 (2.23)
20.46	34.56 (2.67)	0.55 (0.08)	0.42 (0.01)	0.32 (0.09)	6.24 (0.69)
22.47	36.23 (1.99)	0.59 (0.06)	0.44 (0.09)	0.33 (0.01)	5.98 (0.79)
23.08	37.34 (0.89)	0.60 (0.01)	0.46 (1.04)	0.35 (0.04)	5.12 (1.15)
24.39	38.12 (0.76)	0.63 (0.03)	0.48 (0.06)	0.36 (0.07)	4.45 (0.33)

(Standard deviation in parenthesis)

Conclusions

The effect of moisture content on some physical properties of groundnut variety (TMV2), widely cultivated in the state of Odisha, India was investigated with a view to provide important and required data for developing its appropriate handling and processing equipment. The principal dimensions, porosity, true density, angle of repose and static coefficient of friction were found to increase with increase in the specified moisture contents under the study both for pods and kernels of that variety. However, the bulk density and crushing strengths decreased with the increase of moisture contents both for pods as well as kernels. The highest static coefficient of friction was recorded for GI sheet followed by plywood and plastic sheet in both for pods and kernels. The data of moisture dependent properties of agricultural products are very important in order to extend their shelf life. The performance of planting and handling equipment and the safety of the processed products like groundnut lies in the moisture contents at which it is handled. Very high and low moistures may compromise the quality of groundnuts, leading to damage, insect pest attack and possible contamination during handling operation and storage.

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