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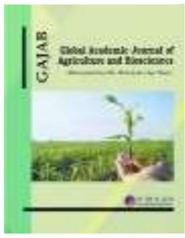

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Research Article

Studies on Some Physical Properties of Groundnut of Devi (ICGV 91114) Variety

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Abstract: Some physical properties of groundnut pod and kernel of variety Devi (ICGV 91114), cultivated in major part of Odisha, have been investigated when their respective moisture contents were 7.98 % and 11.84 % on dry basis. The oil content of kernel was determined to be about 49.67 %. The results revealed that the average pod length, width, thickness and 1000-unit mass were 25.17, 11.67, 11.23 mm; and 799.87 g, while the corresponding values for kernel were 10.41, 6.93, 6.43 mm; and 297.65 g respectively. The sphericity of pod was 21.79 % less than the kernel and surface area was 71.56 % more than that of the kernel. Bulk densities of pod and kernels were 258.94 and 568.94 kg m^{-3}, the corresponding true densities were 472.19 and 948.75 kg m^{-3} and corresponding porosities were 45.12 and 43.33 % respectively. The angle of repose of pod and kernel were 30.87 and 38.76^0 respectively. The coefficient of friction in case of pod was highest for GI sheet (0.45) followed by plywood (0.32) and least in case of plastic sheet (0.22). Information obtained through the experiments would not only be the useful data for engineer in designing planting and post-harvest equipment but also for food scientists, food processor and plant breeders.

Keywords: Groundnut, physical properties, oil seed, moisture content, Devi (ICGV 91114).

INTRODUCTION

The information regarding the physical properties of any biological material such as fruits, seeds, grain etc. are very much necessary for developing appropriate planting and post-harvest machinery. Designing a machine, without taking into consideration of the relevant data on the engineering/physical properties like geometric properties (length, width, thickness, arithmetic mean diameter, geometric mean diameter, sphericity and surface area), gravimetric properties (including unit mass, 1000 grain mass, true volume, true density, bulk density and porosity) and frictional properties (angle of repose and static coefficient of friction) results into its working inefficiency causing the post-harvest losses of the crop and ultimately reduction in the economic benefits for the growers. The knowledge on the above aspects not only therefore helps the engineer engaged in developing mostly post-harvest machinery of the crops for the operations like threshing, decortication, cleaning, grading, drying, storage, transportation and oil extraction, but also act as a ready reckoner for food scientists, food processors, plant breeders etc. especially for processing, nutritional quality, preservation and seeding purposes. One such problem is being faced among the cultivators in Odisha, India, by the use of commercially available power (1 hp) operated cast iron sheller bar type groundnut decorticator. The above unit has been developed and marketed by the manufacturers without referring to the relevant physical properties pertaining to the decortication and winnowing operations of the most widely prevailing variety of groundnut i.e. Devi (ICGV 91114). Studies on the performance of the above decorticator showed low shelling efficiency and high kernel breakages (Paritosh and Ghosal, 2016). As a result, farmers are to go for the traditional hand shelling method resulting into low income from the broken kernels and poor quality seeds for use in sowing purpose. Hence, it needs modification for reducing post-harvest losses and thus to enhance productivity. Besides decortication, the study of the physical properties of the same variety of groundnut provides information for designing the suitable planting and other post-harvesting machinery. The size (such as length, breadth, thickness, arithmetic mean diameter and geometric mean diameter) and shape (sphericity and aspect ratio) are important in designing, separating, harvesting, shelling, sizing and grading of the bio-materials. Bulk density, true density and thousand grain mass are used in determining the size of storage bins and also affects the structural loads. The angle of repose is important in designing storage and transporting structures. Porosity (calculated from bulk density and true density) and surface area affect the resistance to air flow through the bed formed due to bulk of the materials and data on them are necessary in designing the drying process. Fruit part fraction gives an overall idea about the composition of kernel and shell which affect the oil yield of the product. The ability of any grain, fruit or seed to either roll or slide depends on the aspect ratio as well as sphericity. Similarly, in drying process, moisture content is an important parameter to be taken into consideration. Though the literatures regarding agronomic practices and cultivation details of the variety Devi and its oil characteristics are known, no study has been undertaken on its physical properties. Since the size and shape of many local varieties of the same crop are different from each other, thus the aim of the study is to investigate some physical properties of groundnut of cv. Devi cultivated in major parts in Odisha. Decortication is one of the important operations in groundnut cultivation and groundnut is a major oil seed crop grown 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). There is therefore, a need to develop a suitable decorticator as a modification to the existing 1 hp power operated commercially available groundnut decorticator by considering some of the physical properties of the pod and kernel in order improve its shelling performances. The present study is thus undertaken to find out the engineering/physical properties of the pod and kernel of Devi variety groundnut whose characteristics features have been mentioned in Table. 1. The parameters studied include moisture content, oil content, size, 1000-unit mass, fruit part fraction, arithmetic mean diameter, geometric mean diameter, sphericity, aspect ratio, surface area, bulk density, porosity, angle of repose and coefficient of friction.

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.

Moisture and oil content

The moisture content of the pod and kernel were determined separately using American Society of Agricultural Engineers (ASAE) standard method (ASAE, 1989). 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 oil content was determined using AOAC method (1984). The dried sample from the moisture content determination was extracted in a Soxhlet-type extractor with petroleum ether (boiling point 60-80 ^{0}C). The extract was dried for 30 minutes at 90 ^{0}C in a rotary evaporator, cooled and the residual oil weighed. Reported values of pod and kernel are the mean of the five observations.

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).

Fig.1 Measurement of length, width and thickness of groundnut

The length (L), width (W) and thickness (T) of groundnut pod were measured using a vernier slide caliper (Fig. 1) 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). $D_a = (L+W+T) / (3)$ 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). Pod weight affects pod flow and in turn, influences the design of hoppers for pods in processing equipment (Jayan and Kumar, 2004). 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). The sphericity of groundnut pod/kernel was calculated by using the following relationship (Mohsenin, 1986): $\Phi = (LWT)^{1/3}/(L)$

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

Surface area:

Fig. 2 Surface area determination by surface coating method

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 as shown in fig. 2. The surface area was measured by counting the number of squares within the traced marks (Adejumo and Abayomi 2012).

Bulk density

Fig. 3 Measurement of 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). 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). 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. (Fig. 3).

T*rue density*:

Fig. 4. True density determination

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). True density determination is shown in fig. 4.

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). According to Mohsenin (1986), 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

A*ngle 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).

Fig. 5 Determination of angle of repose

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). 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. Fig. 5 shows the photograph of the set up for determination of angle of repose. 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) 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

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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). 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. As shown in the figure below, 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. The photograph for measuring of coefficient of static friction is shown in fig. 6.

Fig. 6 Determination of coefficient of static friction

RESULTS AND DISCUSSION

Moisture and oil content

Table 1. Characteristics of Devi variety Groundnut

Variety	Habit	Duration (in Days)	Avg. yield (q/ha)	Rainfall (mm)	Sowing time		Soil type	Special character
					Rain fed	Irrigated		
Devi (ICGV 91114)	Bunchy	90-95	18	522	May-June	January-March & May-July	Sandy loam, loamy sand	Drought resistant, Spheroidal in shape, moderate resistant to early & late spot.

Table 2. Average moisture and oil content of pod, kernel and shell

Part of the material	Mean values Moisture content (% dry basis)	Oil content (%)
Pod (kernel + shell)	7.98 ± 0.66	9.58 ± 5.68
Kernel	11.48 ± 0.44	49.67 ± 3.58
Shell	5.84 ± 0.22	0

The average moisture and oil content of groundnut pod and kernel are shown in Table 2. The average moisture contents of pod and kernel at the time of experiment were respectively 7.98 % and 11.84 % on dry basis. The kernel contains high moisture compared to the pod. This reflects that drying process needs to be undertaken after the kernel is separated from the pod. The kernel contains 49.67 % oil and shell does not contain oil. Hence, oil extraction needs to be done after separation of kernel from the pod. The oil content of Devi variety is close to that of the other varieties of groundnut (Balasubramanian et al, 2011).

Other Physical Properties

Table 3. Physical properties of groundnut pod (Devi) at m.c. 7.98 % (db)

Sl. No.	Physical properties	No. of sample	Minimum	Maximum	Mean	Standard Deviation
1	Length (mm)	100	22.37	32.04	25.17	2.34
2	Width (mm)	100	11.43	12.97	11.67	0.59
3	Thickness (mm)	100	9.98	13.78	11.23	1.06
4	1000 pod mass (g)	20	801.21	819.06	799.87	9.56
5	Kernel fraction (%)	20	71.23	79.89	74.34	6.58
6	Shell fraction (%)	20	22.21	30.03	26.74	4.36
7	Arithmetic mean dia (mm)	100	14.65	19.43	15.87	2.11
8	Geometric mean dia (mm)	100	13.54	18.02	14.85	3.57
9	Sphericity (decimal)	100	0.57	0.64	0.61	0.95
10	Surface area (mm^2)	100	561.23	961.12	671.85	89.53
11	Aspect ratio (%)	100	39.12	55.43	47.02	7.94
12	Bulk density (kg/m^3)	20	245.67	276.53	258.94	10.64
13	True density (kg/m^3)	20	294.32	647.98	472.19	77.83
14	Porosity (%)	20	40.09	47.68	45.12	3.72
15	Angle of repose (^{o})	20	27.43	35.42	30.87	3.76
16	Static coefficient of friction (GI sheet)	20	0.42	0.46	0.45	0.01
	Plastic	20	0.23	0.24	0.22	0.01
	Plywood	20	0.29	0.33	0.32	0.03

Table 4. Physical properties of groundnut kernel (Devi) at m.c of 11.84 %(d.b)

Sl. No.	Physical properties	No. of sample	Minimum	Maximum	Mean	Standard Deviation
1	Length (mm)	100	8.32	11.89	10.41	1..04
2	Width (mm)	100	6.46	9.03	6.93	0.87
3	Thickness (mm)	100	6.23	8.94	6.43	1.09
4	1000 pod mass (g)	20	291.87	308.67	297.65	5.89
5	Arithmetic mean dia (mm)	100	7.56	8.88	8.03	0.67
6	Geometric mean dia (mm)	100	7.89	8.91	6.89	0.67
7	Sphericity (decimal)	100	0.73	0.93	0.78	0.14
8	Surface area (mm^2)	100	176.05	235.07	191.03	27.05
9	Aspect ratio (%)	100	54.98	94.07	71.23	12.76
10	Bulk density (kg/m^3)	20	567.97	591.74	568.94	8.67
11	True density (kg/m^3)	20	913.67	967.67	948.75	22.37
12	Porosity (%)	20	46.81	49.37	43.33	1.09
13	Angle of repose (^{o})	20	31.06	40.98	38.76	2.09
14	Static coefficient of friction (GI sheet)	20	0.44	0.49	0.46	0.02
	Plastic	20	0.21	0.26	0.23	0.04
	Plywood	20	0.29	0.38	0.36	0.01

The average values of determined physical parameters of pod and kernel are shown in Tables 3 and 4. The pod length, width and thickness were found to be 25.17 ± 2.43, 11.67 ±0.59 and 11.23 ± 1.06 mm respectively. Corresponding values for ICGV 00440 are 34.6 ± 2.4, 14.7 ±0.9 and 14.40 ±0.8 mm (Balasubramanian et al, 2011). Hence Devi is smaller in size and accordingly aperture size needs to be considered in developing the appropriate component of post-harvest equipment. The arithmetic and geometric mean diameters for the pod were 15.87 and 14.85 mm respectively. These values are less than length but more than width and thickness. Shape of the biological material is determined in terms of its sphericity and aspect ratio. The sphericity of pod and kernel of Devi were found to be 0.61 and 0.78 respectively. Corresponding values in case of ICGV 00440 for pod and kernel are close to each other i.e. 0.70. As per the investigations by Garnayak et al., 2008 and Bal and Mishra, 1988, the grain/seed is spherical when the sphericity value is more than 0.70, otherwise considered to be flat. Hence pod and kernel of Devi are considered to be flat and round respectively. The kernel in this case should be treated as an equivalent sphere for the calculation of the surface area. The pod may be treated as a flat for analytical prediction of its drying behavior.

The mean values of aspect ratio for pod and kernel were found to be 47.02 % and 71.23 % respectively. Aspect ratio defining to the ratio of seed width to length indicates the rolling or sliding over a surface. The sphericity and aspect ratio of more than 70% implied that peanut was more as spherical, and tend to rather roll than slide (Dutta et al., 1988). The low value of aspect ratio indicated the tendency to slide than to roll. Hence, the pod would slide but kernel would roll as its aspect value (67 %) is close to the 0.70 (70 %). The tendency to either roll or slide is very important in the design of hoppers and dehulling equipment for the seed.

The 1000 pod and kernel mass are 799.87 and 297.65 g respectively. The corresponding reported values of ICGV 00440 to be 1594 and 784 g are higher than Devi (Balasubramanian et al, 2011).

The surface area of pod is larger than that of kernel by 71.56 %, indicating that mass or energy transfer rate through the surface of the pod might be slower than the rate for kernel.

The mean values of bulk density for pod and kernel were found to be 258.94 and 568.94 kg/m^3 respectively. This indicates that the bulk density of pod is 54.48 % lower than that of kernel. This indirectly implies that pod needs more space per unit mass than kernels. The true density of pod is less than the density of water (1000 kg m^{-3}) due to the air pores between the shell and kernel. The true density of kernel is higher than that of pod. This indicates that the separation of shells from kernel after decortication can be done by blowing air (winnowing). Bulk density is important because it determines the capacity of storage and transport systems.

The mean values of porosity for pod and kernel were found to be 45.12 % and 43.33 % respectively. Since the porosity depends on the bulk as well as true densities, the magnitude of variation in porosity depends on these factors only. The porosity of the bulk of kernel is lower than that of the pod. This also indicates that the aeration of bulk of pod is easier than that of the bulk kernel as porosity determines the resistance to airflow during aeration and drying process.

Adhesion between container wall and material affects the value of angle of repose. The angle of repose of pod is about 25.55 % lower than that of the kernel. This might have been due to the viscous surface and the least hardness of kernels leading to the highest cohesion among the individual kernels and therefore to the higher angle of repose. This value implies the lowest flow ability of kernels compared to the pods.

The coefficient of friction for pod and kernel was determined with respect to three different structural surfaces. It was found that the coefficient of friction for pod was highest against GI sheet (0.45) followed by plywood (0.32) and least in case of plastic sheet (0.22). The least coefficient of friction may be owing to the smoother and more polished surface of the plastic sheet than the other materials used. The data on the coefficient of friction will be important for designing of storage bins, hoppers and conveyors.

CONCLUSIONS

The studies were undertaken to determine the physical properties of groundnut pod and kernel of variety Devi, widely cultivated in Odisha. Planting and post-harvest machinery available commercially in the state are generally not designed on the basis of the physical properties of the prevailing variety of groundnut resulting into their poor performances. Hence investigations were carried out and the experiments were conducted when the average moisture contents of pod and kernel were respectively 7.98 % and 11.84 % on dry basis and oil content of kernel was about 49.67 %. The physical properties of both pod and kernel including their moisture and oil content, 1000-unit mass, dimensions, arithmetic and geometric mean diameter, pod part fraction, sphericity, aspect ratio, surface area, bulk density, true density, porosity, angle of repose and coefficient of static friction have been determined and reported. The information obtained from the present investigations would enlarge the knowledge about the variety Devi and provide useful data for its post-harvest handling not only for decortication purposes but also for other operations of the crop such as planting, sorting, grading, packaging, oil extraction and further industrial processing.

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