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SOME ENGINEERING PROPERTIES OF THREE VARIETIES OF GROUNDNUT PODS AND KERNELS

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Abstract

Some engineering design related physical and mechanical properties of three varieties namely; Manipintar, Local I and Local II of groundnut pods and kernels were determined. This is of prime importance in the design, handling, processing and storage, separation and packaging systems of groundnut. In the study some engineering properties such as dimensions, geometric mean diameter (GMD), sphericity, surface area, bulk density, true density, porosity, volume, Mass, 1000- unit mass, angle of repose, static coefficient of friction on various surfaces and rupture force in 3 axes, were determined at 4.76, 4.04, 4.24 % and 6.29, 6.78, 6.61 % moisture contents dry basis for the three groundnut pods and kernels varieties, respectively. Bulk densities of pods and kernels were 0.27, 0.29 and 0.27 g/cm^3, the corresponding true densities were 0.53, 0.53 and 0.38 g/cm^3 and the corresponding porosities were 47.11, 43 and 28.4% for Manipintar, Local I and Local II respectively for the pods. The mean values of rupture force for groundnut pods of Manipintar through length, width and thickness were 1.19 N/mm, 3.99 N/mm and 5.25 N/mm respectively while that of Local I were 0.84 N/mm, 4.63 N/mm, and 6.50 N/mm respectively. Similarly, Local II has mean values of rupture force as 1.30 N/mm, 4.23 N/mm and 4.9 N/mm through length, width and thickness respectively. Statistical analysis of variance (ANOVA) was carried out to compare the mean values of the physical properties of the three varieties of groundnuts. It shows there was no significant difference at 5 % probability level between their means for groundnut pods. However, for the kernels, the length, width, thickness, GMD, and sphericity all show significant differences at 5% probability level.

Keywords: Groundnut, Pods, kernels, Physical properties, Mechanical properties.

1 Introduction

Groundnut (*Arachis hypogaea*) belongs to the family leguminosae. It has short lived yellow flowers and is grown for its edible oil and protein rich kernels or seeds as an annual crop in tropical and subtropical regions and the warmer areas of temperate regions of the world.
Groundnut, being an herbaceous plant, is of two major varieties; bunch and runner varieties. The bunch varieties are common in the United States, grow 30-40cm in height and do not spread. Then, the runner varieties which is the most common in West Africa, are shorter and run along the ground for 30-60cm. Apart from the above mentioned varieties many intermediate hybrids exist (Asiedu, 1992).

According to investigation carried out by Ntare *et al.* (2012) groundnut is the sixth most important oil producing crop in the world, with about 48-50 % oil and 26-28 % protein. It is also rich in dietary fibre, minerals and vitamins. Over 100 countries worldwide cultivate groundnut with developing countries constituting 94 % of the global production. Groundnut production is concentrated in Asia and Africa recording 56 % and 40 % of the global area and 68 % and 25 % of the global production respectively.

Hamman and Caldwell (1974) reported that apart from groundnut being a major source of vegetable oil, its cake (*Kuli-kuli*) contains concentrated amount of minerals, proteins and vitamins. In short, findings have revealed that no part of groundnut is a waste. The whole crop without the nut can be used as animal feed or may also be used to replenish soil nutrient when it is burnt into ashes (Mohammed and Hassan, 2012).

Inspite of the economic potential of groundnut, the processing operations are predominantly done manually. These operations are time consuming and laborious, inherent unhygienic conditions and poor or unsatisfactory output like high groundnut kernel breakages as a result of shelling. The knowledge of physical and mechanical properties of groundnut like any other agricultural material is of paramount importance in order to facilitates the design and development of equipment for harvesting, shelling, conveying, cleaning, delivering, separation, packing, storing, drying, mechanical oil expelling and processing of the products (Davies, 2009).

The object of the study was to investigate some engineering properties of three different groundnut varieties, namely axial dimensions, unit mass and volume, sphericity, true and bulk densities, porosity, projected area, rupture strength and static coefficient of friction on three structural surfaces; plywood, metal sheet and glass.

2 Materials and Methods

The three groundnut varieties namely; Manipintar, *Kwankwaso* and *Bahaushiya* were collected in 2014 which were the available varieties in the study area (Dawanau market of Kano Sate) at the the time of the study. The groundnut varieties are Manipintar, *Kwankwaso* and *Bahaushiya* referred to as '*Local I'* and '*Local II*' respectively. They were cleaned to remove all foreign matter such as dust, debris, stones, immature and broken pods and kernels. The initial moisture content of groundnuts for the three varieties Manipintar, *Kwankwaso* and *Bahaushiya* were determined by the standard method described by (Chakraverty, 2004) and were found to be 4.76, 4.04, and 4.24 % for the pods and 6.29, 6.78, 6.61 % for the kernels d.b. for the pods, respectively. All the physical properties of the peanut were determined at these moisture levels with three replications at each level. And for the mechanical properties, ten samples of the groundnut pods and kernels were tested for each of length, width and thickness loading direction and repeated for each of the three varieties.

2.1 Physical Properties of Groundnut Pods and Kernels

One hundred (100) kernels and 100 pods of each variety were selected for the experiment, in order to determine the size and shape of the groundnut. For each groundnut pod (Figure 1) and kernel, the three principal dimensions, namely length, width and thickness were measured using a digital micrometer screw gauge with an accuracy of 0.01 mm.
The geometric mean diameter, *D*, arithmetic mean diameter, D_a and Sphericity, S of the pods and kernels were calculated using Mohsenin (1986) relationship as follows:

$$D = (LWT)^{1/3} \quad (1)$$

$$D_a = \frac{(L + W + T)}{3} \quad (2)$$

$$S = \frac{(LWT)^{1/3}}{L} \quad (3)$$

where: L = length (mm), W = width (mm) and T = thickness (mm) (Fig. 1.).

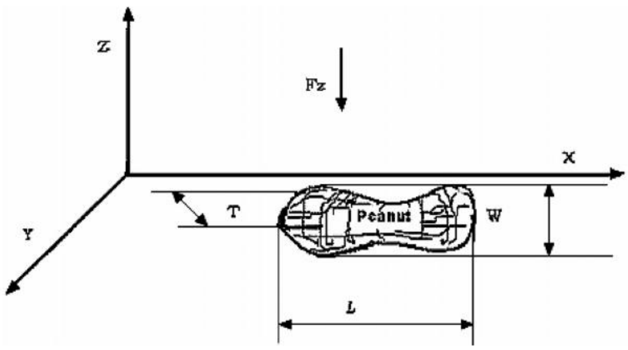

Figure 1: Three major axial dimension of groundnut

Source: Aydin (2007)

To obtain the mass, each groundnut sample was weighed by a digital weighing balance reading to an accuracy of 0.001 g.

Surface area, A was calculated from the relation given by McCabe et al. (1986) as:

$$A = \pi D^2 \text{ (cm}^2\text{)} \quad (4)$$

The true density of a groundnut sample was defined as the ratio of the mass of a sample of the groundnut to the solid volume occupied by the sample (Mohsenin, 1986; Joshi *et al*., 1993). The groundnut volume and its true density were determined using the water displacement method. The bulk density was determined as described by (Mohsenin, 1986; Jafari *et al*., 2011). It was determined by pouring the groundnuts in the calibrated cylinder from a height of about 15 cm up to its brim and excess groundnuts were removed by strike off stick. The groundnuts were compacted by taping the cylinder three times for the material to consolidate. The weight of the sample was obtained by subtracting the weight of the container from the total weight of cylinder and sample. The following equation was used to compute the bulk density:

$$\rho_b = \frac{M}{V_b} \quad (5)$$

where: ρ_b = bulk density (g/cm^3), M = mass of seeds (g), V = volume of seeds (cm^3), ρ_t = True density (g/cm^3).

The porosity (*P*) of bulk groundnut pods and kernels were computed from the values of true density and bulk density using the relationship given by Mohsenin 1986) as follows:

$$P = \frac{\rho_t - \rho_b}{\rho_t} \times 100 \quad \% \tag{6}$$

Moisture Content on dry basis, MC_{db} was determined by oven dry method at 130^{o} C for 6hrs as reported by Chakraverty (2004); ASAE, (1983). It was calculated on dry basis using:

$$MC_{db} = \frac{W_i - W_d}{W_d} \times 100 \ (\%) \tag{7}$$

where: W_i = Initial mass of sample (g) and W_d = Dried mass of sample (g)

The Angle of repose (θ) was determined by using wooden box and two plates; fixed and adjustable as shown in Figure 2. The wooden box was filled with the groundnut sample and plate on the tilting top of the adjustable plate. The adjustable plate was gradually tilted until the materials start to move along the inclined surface. The angle of inclination was recorded from the adjustable protractor attached to the fixed plate as the angle of repose for the groundnut sample (Sahay and Singh, 2003).

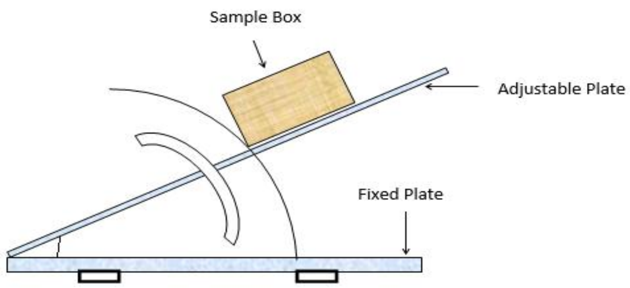

Figure 2: Determination of static (empting) angle of repose

Static coefficient of friction, μ_s is the ratio of the force required to start sliding the sample over a surface to the normal force (Bahnasawy, 2007). The static coefficient of friction of groundnut pods and kernels against different surfaces; namely steel sheet, plywood, and glass was determined. A wooden box of 10 cm length, 10 cm width and 6 cm height without base and lid was filled with groundnut sample and placed on the adjustable tilting plate (fig.2). The inclination of the adjustable plate was increased gradually until the box with the sample just started to slide down and the angle between the inclined surface and the horizontal (fixed plate) was recorded from adjustable protractor, the tangent of which gave the static coefficient of friction as stated in Equation (8). These methods were used by other researchers including Gupta and Das (1997), Baryeh (2002) and Bart-Plange and Baryeh (2003):

$$\mu_s = \tan\theta \tag{8}$$

where: θ = angle between the inclined surface and the horizontal at which samples just start to slide down. Three replications for each groundnut sample were made.

Analysis of Variance using SAS 9.0 was used to compare the varietal differences in the physical properties of the three varieties of groundnuts for both pods and kernels.

2.2 Mechanical Properties of Groundnut Pods and Kernels

Mechanical properties such as rupture force, deformation at rupture point, hardness and energy used for cracking the groundnut pods and crushing kernels were determined.

The rupture force indicates the minimum force required to break the groundnut pods and it must be exceeded to expose the kernel from the pod. It was determined from forces acting on pods and kernel as reported by Adgidzi *et al.* (2006). Ten samples of the groundnut pods and kernels were tested for each of length, width and thickness loading direction and repeated for each of the three varieties. The individual samples were loaded between two parallel plates on Instron Universal Testing machine (Figure 3) (model; Santam STM-5 with measurement accuracy of 0.001N force and 0.001mm of deformation) and compressed at a loading speed of 5mm/min until fracture occur (Kita and Figiel, 2007). Once initial crack is noticed, the loading was stopped. Thus the rupture force and deformation at rupture point were displayed on a screen automatically. This experiment was conducted at material science laboratory of Mechanical Engineering of Ahmadu Bello University, Zaria.

Deformation ratio (axial strain) at rupture point is the ratio of the deformation at rupture point to the dimension of sample in the direction of compressive force at the loading point.

Adgidzi *et al.* (2006) defined Hardness as the ratio of the rupture force and deformation at rupture point.

The energy needed to crack the groundnut pods was obtained from Kick's relation and was given by (Mohammed and Hassan, 2012) as:

$$E = K_k F_c \log_e \frac{L_1}{L_2} \qquad (\mathrm{kg/ms^2}) \qquad (9)$$

Where, E = Energy required to shell, K_k = Kick's Constant = 1.2, F_c = Crushing strength of groundnut (N/m), L_1 = Average length of unshelled groundnut (m), L_2 = Average length of shelled groundnut (m).

Figure 3: Instron Universal Testing machine

3 Results and Discussion

3.1 Physical Properties

3.1.1 Moisture Content

The initial moisture content for the samples were determined and maintained throughout the experiment. Moisture content of 4.76, 4.04, and 4.24 % were recorded for Manipintar, Local I and Local II pods, respectively. Similarly, 6.29, 6.78 and 6.61 % values were recorded for kernels of same three varieties, respectively.

3.1.2 Physical Properties of Groundnut Pods

Table 1 presents the summary results of all the physical parameters measured. The length of groundnut pods was found to have an average value 27.38 mm in Manipintar, 28.40 mm in Local I and 28.50 mm in Local II. The width and thickness for the three varieties of groundnut pods ranges from 12.78 mm and 13.25 mm in Manipintar to 13.24 mm and 12.06 mm in Local I, 11.93 mm and 11.48 mm in Local II, respectively. These dimensions will however determine the size of the hopper outlet, concave openings and the shelling drum and concave clearance of any groundnut shelling machine as reported by Maduako and Hamman (2004). The Geometric mean diameter also ranges from 16.28 mm in Manipintar to 16.5 mm in Local I and 15.73 mm in Local II. Also the arithmetic mean diameter for the three varieties is 17.80 mm, 19.90 mm and 17.30 mm respectively as shown in Table 1. These results are slightly differ to that of Samnut-22 and Ex-Dakar groundnut pods varieties reported by (Odesanya *et al.*, 2015).

The mean values of the sphericity of the groundnut pods ranges from 55.35 in Local II to 60.74 in Manipintar and 59.11 in Local I. However, among the three varieties, Manipintar has the highest mean sphericty of 60.74. This result is slightly closer to that reported by Maduako and Hamman (2004) for ICGV-SM-93523 RMP-9 and RMP-12 as 44.0, 54.1 and 52.3, respectively.

The result of the groundnut pods for Thousand Seed weight is shown in Table 1. The values obtained for mean thousand seed weight were 155.80, 145.10, and 185.87g for Manipintar, Local I and Local II respectively. This thousand seed weight is significant in estimating the size of hopper and size of shelling chamber, and will be also useful in determination of the stability of the machine during operation.

The results for the mean surface area of the pods are shown in Table 1. It ranges from 780.30 to 865.39 mm^2 for the three varieties. The result slightly differ than that reported by Odesanya *et al.* (2015) for Samnut 22 with 307.15 mm^2 and Ex-Dakar with 281.8 mm^2. Sharma *et al.* (2011) opined that the surface area is important in determining the shape of the seeds and this will be an indication of the way the seeds will behave on oscillating surfaces during processing of such product.

The results for the true and bulk densities of groundnut pods are shown in Table 1 and ranges from 0.38 to 0.53 g/cm^3 and 0.27 to 0.29 g/cm^3 respectively for the three varieties. The highest mean true and bulk densities were recorded with Local I that is 0.53 and 0.29 g/cm^3, respectively whereas the least mean true and bulk densities were observed with Local II. This is comform with that reported by Maduako and Hamman (2004).

The result of porosity for groundnut pods ranges from 28.40 to 47.11% for the three varieties (Table 1). During aeration, drying process or winnowing process, Sharma *et al.* (2011) observed that porosity of the mass of seeds determines the resistance to airflow.

As can be seen in Table 1, the mean values of angle of repose of the pods are 32.67° in Manipintar; 32.33° in Local I and 32.67° in Local II. As it can be observed, the angle of repose for the pods is greater than that of the kernels; probably it might be due to the roughness of the surfaces and irregular nature of the pods. Thus, the pods tend to stick to one another thereby giving rise to a larger angle of repose than the kernels (Maduako and Hamman, 2004).

The static coefficient of friction for groundnuts was determined with the respect to three difference structural surfaces. The mean static coefficient of friction for pods on plywood, glass and galvanized steel are 0.50, 0.30 and 0.43 for Manipintar, 0.46, 0.32 and 0.41 for Local I while 0.46, 0.29 and 0.41 are for Local II respectively as can be seen in Table 1. Sahay and Singh (2003) stated that the static coefficient of friction is important in designing of storage bins, hoppers, pneumatic conveying system, screw conveyors, shelling and threshing machines, etc.

Table 1: Geometric Properties of three varieties of groundnut pods

	Varieties		
Geometric Properties	**Manipintar**	**Local I**	**Local II**
Length, mm	27.38	28.40	28.50
Width, mm	12.78	13.24	11.93
Thickness	13.25	12.06	11.48
Geometric Mean Diameter, (GMD) mm	16.28	16.5	15.73
Arithmetic Mean Diameter, (AMD) mm	17.80	17.90	17.30
Sphericity, %	60.74	59.11	55.35
Surface area, mm^2	846.92	865.39	780.30
Unit Volume, cm^3	300	276.67	276.67
Bulk Volume, cm^3	493.33	463.33	446.67
Thousand Seed Weight, g	155.80	145.1	105.87
True density, g/cm^3	0.53	0.53	0.38
Bulk density, g/cm^3	0.27	0.29	0.27
Porosity, %	47.11	43.00	28.40
Angle of repose	32.67	32.33	32.67
Coefficient of Friction on Various surfaces:			
• Plywood	0.50	0.46	0.46
• Glass	0.30	0.32	0.29
• Galvanize Sheet	0.43	0.41	0.41

3.1.3 Physical Properties of Groundnut Kernels

The summary of results of physical properties for the three varieties of groundnut kernels is presented in Table 2.

The length, width and thickness for the kernels of all the three varieties are 13.84 mm, 8.06 mm and 8.03 mm in Manipintar, 10.61 mm, 7.79 mm and 6.81mm in Local I, and 17.61 mm, 8.89 mm and 9.01 mm in Local II respectively. For the geometric mean diameter, the kernels have average values of 9.61 mm, 8.22 mm and 11.18 mm for all the three varieties respectively and this property will determine the dimensions of concave openings in any groundnut shelling machine. Also the arithmetic mean diameter for the three varieties are 9.98 mm, 8.40 mm and 11.84 mm respectively as shown in table 2. All these dimensions slightly differ from RMP 9, ICGV and RMP 12 groundnut varieties reported by Maduako and Hamman (2004) which may be due to varietal difference.

Table 2 shows the mean values of sphericity as 69.70 in Manipiatar, 78.24 in Local I and 64.20 in Local II for the kernels. In comparing the varieties, Manipiatr tends to be more spherical, the least mean sphericity was found to be with Local II, 64.20. These values of sphericity indicate that the kernel can roll in all the three varieties. The probability of sliding is very high for the kernels with sphericity values of between 50 % and 100 %. These results are slightly lower than that obtained by Odesanya *et al.* (2015) for Samnut-22 and Ex-Dakar with sphericity of 0.75 and 0.84, respectively.

The mean values for the groundnut kernels are 52.13, 34.63, 42.83g for Manipintar, Local I and Local II, respectively. Among the three varieties, Manipintar has the highest mean of thousand seed mass of 52.13 and Local I have the least (Table 2). This thousand seed weight is significant in estimating the size of hopper and size of shelling chamber, and will be also useful in determination of the stability of the machine during operation.

The results for the surface area of the kernels range from 212.58 to 393.06 mm^2 for the three varieties (Table 2). Odesanya *et al.* (2015) reported a slightly similar result for Samnut 22 with 149 mm^2 and Ex-Dakar with 97 mm^2 surface area.

True and bulk densities of groundnut kernels are shown in Table 2 and ranges from 0.87 to 1.08 g/cm^3 and 0.55 to 0.82 g/cm^3 respectively. This result is in line with that obtained by Maduako and Hamman (2004). The bulk density of groundnut pods is an important tool in determining the size and capacity of hopper of a groundnut shelling machine. The density of groundnut seeds is important in estimating the maximum load per unit area that the seed separators of a groundnut sheller can withstand without collapsing. Thus the true density of the groundnut is less than that of water (1000 kg/m^3). This shows that the groundnuts are lighter than water and will float in the water. This characteristic can be used to separate the groundnuts from other heavier foreign materials.

Result for the porosity of the kernels shown in Table 2 ranged from 24.70 to 37.00 %. Of the three varieties, Local II has the highest mean porosity of 37.00 %, followed by Local I with 28.89 %. Manipintar recorded the least mean porosity of 24.70 %.

The angle of repose for kernels of all the three varieties recorded were; 28.00° for Manipintar, 26.67° for Local I and 29.00° for Local II (Table 2). Its obvious to observed that the angle of repose for the kernels is less than that of the pods, this might be due to the smoothness and polish nature of the kernels' skin. Thus, making the kernels to slide one another easily, thereby giving rise to a lesser angle of repose than the pods.

The mean values for static coefficients of friction for kernels on plywood, glass and galvanized steel are 0.50, 0.32 and 0.44 for Manipintar, 0.50, 0.30 and 0.41 for Local I while 0.48, 0.33 and 0.48 are for Local II respectively (Table 2). The least static coefficient of friction was observed with glass while the highest static coefficient of friction was observed with plywood. It was observed that the smoother and more polished structural surface, the lower the static coefficient of friction of the samples. Similar results were recorded by various researchers like Davies (2009); Maduako and Hamman (2004); Odesanya *et al.* (2015).

Table 2: Geometric Properties of three Varieties of Groundnut Kernels

	Varieties		
Geometric Properties	**Manipintar**	**Local I**	**Local II**
Length, mm	13.84	10.61	17.61
Width, mm	8.06	7.79	0.656
Thickness	8.03	6.81	
Geometric Mean Diameter, (GMD) mm	9.61	8.22	11.18
Arithmetic Mean Diameter, (AMD) mm	9.98	8.40	11.84
Sphericity, %	78.70	69.24	64.20
Surface area, mm^2	292.61	212.58	393.06
Unit Volume, cm^3	48.33	35.67	49.00
Bulk Volume, cm^3	76.33	64.33	75.67
Thousand Seed Weight, g	52.13	34.63	42.83
True density, g/cm^3	1.08	1.00	0.87
Bulk density, g/cm^3	0.82	0.71	0.55
Porosity, %	24.70	28.89	37.00
Angle of repose	28.00	26.67	29.00
Coefficient of Friction on Various surfaces:			
• Plywood	0.50	0.50	0.48
• Glass	0.32	0.30	0.33
• Galvanize Sheet	0.44	0.41	0.48

3.2 Analysis of Variance on Varietal Differences for Groundnut Pods and Kernels

The analysis of variance carried out to compare the varietal differences in the physical properties of the three varieties of groundnuts is shown in Table 3. The result shows that there is no significant difference at 5 % probability level between the means of the three varieties for the groundnut pods. This implies that one machine can handle the shelling operation for all the three varieties of groundnuts. For the kernels however, length, width, thickness, Geometric Mean Diameter (GMD), and sphericity all show level of significance at 5% probability level. These significant factors were further analysed using Least Significant Difference (LSD) and the results are presented in Table 4. The mean length of Local II is statistically higher than that of Manipintar and Local I. Similarly, the mean width of Local II and Manipintar are statistically similar and the later having the mean width and differ from Local I. The mean thickness of Local II and Manipintar are statistically at par and differ from Local I. The mean GMD of the three varieties are statistically different with Local II having the highest mean GMD. The mean sphericity of the Manipintar and Local I are statistically similar and the later differ from Local II with Manipintar having the mean sphericity.

Table 3: Test of Significance of Varietal Difference for Groundnut Pods and Kernels

S/N	Physical properties	PODS			KERNELS		
		Computed F-Ratio	**Tabular F Ratio**		**Computed F-Ratio**	**Tabular F Ratio**	
			5%	**1%**		**5%**	**1%**
1	Length	0.23NS	3.35	2.51	50.03**	3.35	2.51
2	Width	0.75NS	3.35	2.51	4.19**	3.35	2.51
3	Thickness	0.45NS	3.35	2.51	16.49**	3.35	2.51
4	GMD	0.49NS	3.35	2.51	56.11**	3.35	2.51
5	Sphericity	1.20NS	3.35	2.51	8.41**	3.35	2.51
6	True density	1.41NS	5.14	3.46	0.00NS	5.14	3.46
7	Bulk density	0.23NS	5.14	3.46	0.53NS	5.14	3.46
8	Porosity	0.90NS	5.14	3.46	3.08NS	5.14	3.46
9	Angle of Repose	0.33NS	5.14	3.46	2.89NS	5.14	3.46
10	Coeff. of Friction on surfaces of:						
	• Plywood	2.17NS	5.14	3.46	0.72NS	5.14	3.46
	• Glass	3.08NS	5.14	3.46	2.00NS	5.14	3.46
	• Galvanize Sheet	1.62NS	5.14	3.46	0.11NS	5.14	3.46

* - Significant ** - Highly Significant NS – Not Significant

Table 4: LSD test for Varietal Difference of the three Groundnut Kernels Varieties

Groundnut Variety	Length		Width		Thickness		GMD		Sphericity	
	Mean	**LSD**	**Mean**	**LSD**	**Mean**	**LSD**	**Mean**	**LSD**	**Mean**	**LSD**
Manipintar	13.84	b	8.06	a, b	8.03	a	9.61	b	69.71	a, b
Local I	10.61	c	7.79	b	6.80	b	8.22	c	78.24	a
Local II	17.61	a	8.89	a	9.01	a	11.18	a	64.20	b

Means with the same letter are not significantly different

3.3 Mechanical Properties

The mean rupture force of groundnut pods through length, width and thickness are presented in Table 5 in which the result shows that the highest rupture force for the three varieties was observed along the thickness loading direction. Intermediate rupture force was observed in the width loading direction. However, the minimum rupture force was observed in length loading direction. This slightly differ from that reported by Aydin (2007) where the highest rupture force was obtained while loading along the width direction. This may be due to varietal difference. This mechanical parameter and the direction of minimum rupture is very important parameter in designing of equipment for shelling, milling handling, storage, transportation etc. Insufficient data on mechanical properties might lead to mechanical damage to pods and kernels in processing operations which causes reduction in germination power, viability of seeds, increase chnaces of insect and pest infestation and also affect the quality of the final product.

Table 5: Rupture Force of Groundnut Pods through length, width and thickness

Rupture force through 3-axis, N/mm	Varieties		
	Manipintar	Local I	Local II
Length	1.19	0.84	1.30
Width	3.99	4.63	4.23
Thickness	5.25	6.50	4.90

3.4.1 Interpretation of Force - Deformation Curves of Manipintar Groundnut Pods

The force-deformation curves of Manipintar groundnut pods are show in Figure 4. At small loading, all the forces applied result in stretching the cell walls of the groundnut pods for all the three loading directions which results in an initial straight line portion of the curve A-B. This approximately obeys Hooks' law. As the load increases beyond point B, elasticity of the cell wall is exceeded thus, cell wall which is assumed to be viscous now bear the load resulting into change in linearity of the curve attempting to follow that of viscous materials. At point C, the cell wall cracks and the void space is displaced hence the abrupt change in the curve. Continuous loading results in rupture of the pod at point D. Thus, the value of the force at point D is that which is required to crack the pod. D-E is the breakage region where the groundnut pod is completely crushed. It could be observed that the groundnut pod is subjected to the highest rupture force along the thickness loading direction (T) whereas along the length loading direction, the least rupture force was observed.

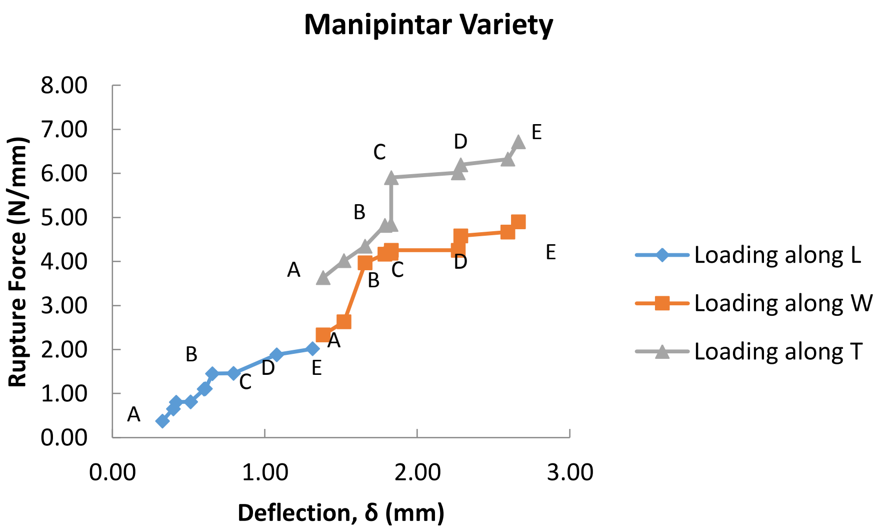

Figure 4: Deformation Curve for Manipintar groundnut pods variety

3.4.2 Interpretation of Force - Deformation Curves of Local I Groundnut Pods

Similarly for Local I groundnut variety, the force-deformation curve (Figure 5) for the three loading direction were presented. Initially, small loading results in the cell wall of the groundnut pods being stretched as indicated by the straight line of the curve A-B which approximately obeys Hooks' law. When the load is gradually increased beyond point B, the elasticity of the cell wall of the pod is exceeded which consequently result in change of linearity of the curve as such attempt to follow path of viscous material. At point C, the cell wall cracks and the void space is displaced hence the abrupt change in the curve. Continuous loading results in rupture of the pod at point D. However, the value of the force at this point is that which is required to crack the pod. D-E is the breakage region where the groundnut pod is completely crushed. It is evident from the figure that the groundnut pod is subjected to the highest rupture force along the thickness (T) loading direction and least rupture force along the length loading direction.

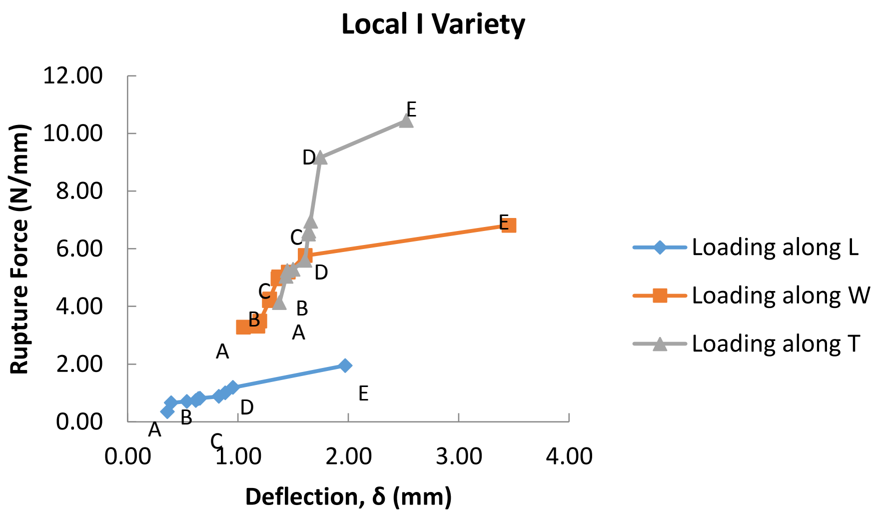

Figure 5: Deformation Curve for Local I variety groundnut pods variety

3.4.3 Interpretation of Force - Deformation Curves of Local II Groundnut Pods

The force-deformation curves of Local II groundnut pods are show in Figure 6. At initial small loading, all the forces applied result in stretching of the cell walls of the groundnut pods at all the three loading directions. This results in an initial straight line portion of the curve A-B which approximately obeys Hooks' law. When the load is increased beyond point B, elasticity of the cell wall is exceeded thus, the cell wall which is assumed to be viscous now bear the load resulting into change in linearity of the curve attempting to follow that of viscous materials. At point C, the cell wall cracks and the void space is displaced hence the abrupt change in the curve. Continuous loading results in rupture of the pod at point D. Thus, the value of the force at point D is that which is required to crack the pod. D-E is the breakage region where the groundnut pod is completely shattered. From the figure it could be observed that the groundnut pod is subjected to the highest rupture force along the thickness (T) loading direction whereas the least rupture force loading was along length loading direction.

4 Conclusion

This work was carried out to study some physical and mechanical properties of three different groundnut verities namely: Manipintar, Local I and Local II that are affecting design and development of handling, processing and storage equipment of both pods and kernels. The physical properties that were determined includes size, shape, surface area, weight, true density, bulk density, porosity, moisture content, angle of repose, static coefficient of friction and moisture content. The mean surface area for the pods was 636 mm^2 for the three varieties while the average weight, true density, bulk density and porosity are 135.59 g, 0.48 g/cm^3, 0.28 g/cm^3 and 39.5% respectively. For the kernels, the mean surface area was 299.42 mm^2 for the three varieties while the average weight, true density, bulk density and porosity are 43.2 g, 0.98 g/cm^3, 0.69 g/cm^3 and 30.2% respectively. The mean moisture content for the pods at which the experiment was carried out was 4.34% while that of the kernels was 6.47%. The angle of repose for the three groundnut varieties investigated; Manipintar, Local I and Local II averaged 32.67°, 32.33° and 32.67° for the pods while 28°, 26.67° and 29° are for the kernels, respectively, while the coefficient of friction of the pods averaged 0.47 on plywood, 0.3 on glass and 0.42 on galvanized steel. And for the kernels, the coefficient of friction averaged 0.49 on plywood, 0.32 on glass and 0.44 on galvanized steel.

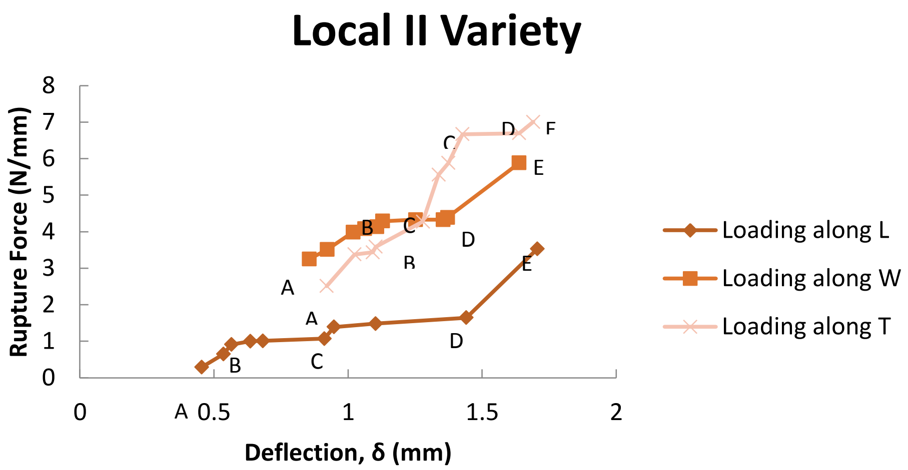

Figure 6: Deformation Curve for Local II groundnut pods variety

In order to minimize kernel breakage, there is need to sort the groundnut pods based on these physical properties since it was observed that there was no significant difference at 5 % probability level between the means of the physical properties for the three varieties for the groundnut pods before embarking on designing groundnut sheller. Local II is has highest mean length, width thickness, and GMD whereas Manipintar has the mean sphericity.

The mean values of rupture force for Manipintar pods along length, width and thickness were 1.19 N/mm, 3.99 N/mm and 5.25 N/mm respectively while that of Local I pods were 0.84 N/mm, 4.63 N/mm, and 6.50 N/mm respectively. Also Local II pods have mean values of rupture force as 1.30 N/mm, 4.23 N/mm and 4.9 N/mm along length, width and thickness respectively. The highest rupture force for the three varieties was obtained while loading along the thickness loading direction (F_z-axis) and having mean moisture content of 4.04 % d.b. Generally the groundnut become soft at high moisture content hence they required less force to rupture. These results agree with Aydin (2007).

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