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DETERMINATION OF SOME PHYSICAL AND MECHANICAL PROPERTIES OF HORSE EYE BEAN *(mucuna sloanei)* FROM SOUTH EASTERN NIGERIA.

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ABSTRACT

Selected physical and mechanical properties of horse eye bean (*mucuna sloanei*) were studied at different moisture content levels of 11.5%, 13% and 17% (d_b). Compression strength characteristics were conducted under quasi-static compressive force at longitudinal and latitudinal (lateral) loading positions and the rupture forces, compressive strength, modulus of deformability, toughness, stiffness and force at bio-yield point determined as the mechanical properties. Results indicated that volume (20.137 - 21.856 mm^3), surface area (598.362 - 720.208 mm^2), geometric mean diameter (24.98 - 27.12 mm), and weight (7.625 - 9.203 g) of the velvet bean seed increased linearly with increase in moisture content. Also, the bulk density, specific gravity (0.378 - 0.421 g/mm^3), sphericity (0.882 - 0.831) and aspect ratio (0.974 - 0.726) decreased linearly with increase in moisture content. These indicate that Velvet beans have wide size ranges and no single sample of the grains can effectively represent the other. In the case of the force-deformation characteristics, result indicates that the force and corresponding deformation to rupture of velvet bean seeds were found to vary from 400N - 2500N and 3mm - 10.25mm in longitudinal loading positions and 800N - 2800N, 3.5mm - 11.5mm in lateral loading positions at the various moisture contents. The bio-yield force, compressive strength, stiffness and toughness of the velvet bean seeds varied from 400N - 1000N, 1.30 N/mm^2 - 8.03 N/mm^2, 120N/mm - 833N/mm and 142.027 J/mm^3 - 656.570 J/mm^3 respectively in longitudinal loading positions to 600N - 2100N, 2.221 N/mm^2 - 9.047 N/mm^2, 57.14 N/mm^2 - 800 N/mm^2 and 486.666 N/mm^2 - 857.046 N/mm^2 respectively in lateral loading position at the various moisture contents. Generally, the compressive strength of the horse eye bean seeds is higher at lateral loading position than at the longitudinal loading position.

Key Words: Physical Properties, Mechanical Properties, Horse eye Bean, Moisture content, Loading Positions.

INTRODUCTION:

This research work determines the physical and mechanical properties of horse eye bean (*mucuna sloanei*). The need to develop modern technology for food production, handling, harvesting, storage, processing, preservation, quality evaluation, distribution and marketing, as well as utilization, trading and development of new varieties requires a good knowledge of the physical and mechanical properties of agricultural and biological materials, (Mohsenin, 1986; Oluka and Nwuba, 2001). This is as a result of the various production processes food materials and agricultural materials are subjected to which includes physical and mechanical operation processes. *Mucuna* plants have more than 100 accepted species of climbing vines and shrubs. *Mucuna Sloanei* is one of legumes found in the tropical and sub-tropical regions of the world, (Nwosu, 2011). It is known to have originated from Asia and introduced into the western hermisphere via Mauritus (Nkpa, 2004). It is mostly found in the Savana areas, rivers/lake borders, swampy forest or wetlands. The seed is commonly called horse eye bean because of its similarity to the eye of a bull. It is also called sea bean because they are mostly carried by rivers into the ocean, (Keller, 2002). Due to its nature as cover crop, it serves as a cover crop to bothyam or maize. It is profiling and like other legumes, yields many fruits per plant and bears one to eight seeds per fruit (Okigbo, 1998). *Mucuna Sloanei* has other local names with respect to different tribes and ethnic groups. In Nigeria, it is called 'Ukpo' by the Ibos, 'Karasuu' by the Hausas, 'Yerepe' by the Yourbas (Nwosu, 2011), and 'Ibabat' by the Efiks, (Obochi et al. 2007). Nutritionally; and constituently, it contains a high level of protein and lysine (a basic amino acid essentially nutritive in vertebrates diet), and are usually limited in the sulfur containing amino acids particularly methionine, (Nwosu, 2011). It also contains crude proteins, carbohydrates, fats, crude fibers, moisture, ash phosphorus, magnessium, calcium, sodium, iron, manganese, copper, tannis, glycosides, L-Dopa (a chemical that is made and used as part of the normal biology of humans, some animals and plants) and Zinc, (Nwosu, 2011; Giami and Nwachukwu, 1997; Akpata and Muachi, 2001; Ijeh et al. 2004; Tuleun et al. 2008). *Mucuna Sloanei* is also used in various soup preparation as soup thickener, (Ezueh, 1997). As a result of its gelation properties and gummy texture when used in soup, makes it desirable when eating 'garri," pounded yam etc., (Nwosu, 2011). It also has medicinal qualities were by the seeds are being used in cooking for pregnant women to avoid miscarriages, (Ahajuoku, 1980). Antidiabetic, (Dhawan et al. 1990), Antiparkinsonism, (Hussain and Manyam, 1997; Molloy et al. 2006), anti-oxidant and anti microbial). Aphodisial, anti neoplastic, enhances learning and memory, (Poornachandra et al. 2005) and antihelminthic, (Jalalpure et al. 2007). It is very essential that the various food materials and agricultural materials are explored to ensure natural benefits which will in turn improve and sustain the good quality life and existence of man. Therefore, the main objective of this research work is to determine the physical and mechanical properties of horse eye bean (mucuna sloanei) prior to processing.

Fig.1: Diagram of horse eye bean inside the Husk

Fig.2: Diagram of horse eye bean

MATERIALS AND METHOD

Physical Properties

The horse eye bean (*mucuna sloanei*) seeds that were used for this research were obtained from Ebonyi State Agricultural Development Center, EBADEP. The seed samples were properly cleaned to avoid alterations and errors with the results. After which the seeds were taken to bioprocessing laboratory of the department of Agricultural and Bioresource Engineering, Enugu State University of Science Technology where the research was conducted to ascertain the physical properties of the horse eye bean (*mucuna sloanei*). Some of the apparatus used includes a 0-25mm range of vernier caliper used to measure the major diameter, the intermediate diameter and the minor diameters of the seed. Also, a Mettler Toledo electronic digital weighing balance of model XP204 was used to measure the weight of the seeds. This experiment was conducted at three different moisture contents 11.5%, 13% & 17 dry base (d.b). The average diameter was calculated by using the arithmetic mean and geometric mean of the three axial dimensions as expressed in equations 1 and 2. The Arithmetic mean diameter (AMD) and Geometric mean Diameter (GMD) of the seeds were determined using equations as expressed by Mohsenin, 1986.

$$AMD = \frac{a + b + c}{3} \quad - \quad - \quad - \quad (1)$$

$$GMD = (abc)^{\frac{1}{3}} \quad - \quad - \quad - \quad (2)$$

where: *AMD* = arithmetic mean diameter; *GMD* = geometric mean diameter; *a* = major diameter (mm); *b* = intermediate diameter (mm); and *c* = minor diameter (mm).

The sphericity (*s*), (%) was determined using the following relationship (Mohsenin, 1986);

$$3 = \frac{(abc)^{1/3}}{a} = \frac{GMD}{a} \quad - \quad - \quad - \quad (3)$$

The surface area, ***A*** (mm^2) of the seeds were obtained using the relationship given below as suggested by [19];

$$A = \frac{\lambda d^2}{4} \quad - \quad - \quad - \quad (4)$$

Where, A = surface if the seeds and d = minor Diameter

The unit volume of 30 seeds each was determined from the values of major, intermediate diameters and minor diameters (a, b and c respectively) from the following relationship,

Where, V = volume of the seeds (mm^2), I=major diameter (mm), and

b = intermediate diameter (mm) and c = minor diameter (mm)

A Mettler Toledo electronic weighing balance of model XP204 and 0.001g sensitivity was used to determine the weight of the seeds. The measurements were replicated for 30 times and the total weight of 30 seeds were determine likewise the mean. The seeds were put into a container with known weight and volume from a height of 150mm at constant rate, (Oduma et al. 2013). Bulk density was calculated from the weight of the seeds divided by the volume.

$$\text{bulk density } eb = w/v \quad - \quad - \quad - \quad (6)$$

eb = bulk density, (g/mm^3), W = weight of the seeds (g)

and V = volume of the seeds (mm^3)

Specific Gravity is the ratio of the density of a solid or liquid to the density of water at 4°C. The term can also refer to the ratio of the density of a gas to the density of dry aim at standard temperature and pressure.

$$\text{Specific gravity} = \frac{\text{Weight of the substance}}{\text{Weight of equal amount of water}} \quad - \quad (7)$$

or

$$\text{Density gravity} = \frac{\text{Density of the substance}}{\text{Density of equal amount of water}} \quad - \quad (8)$$

The research was conducted under three (3) different moisture contents 11.5%, 13% and 17% (wb) respectively. The oven dry method of moisture content determination using a multi-purpose drying oven (OKH-HX-IA) drying oven, was used to determine the moisture content of the seeds. The weight of the dry samples and the weight of the wet samples were determined and the moisture content evaluated from equation 9.

$$M.C. = \frac{Ww - Dw}{Dw} \times 100\% \quad - \quad - \quad - \quad (9)$$

Where, Mw = Moisture Content (%), Ww = Weight of wet sample (g) and
Dw = Weight of dry sample (g)

Determination of the Mechanical Properties:

The compressive test was conducted at the Agricultural and Bioresource Engineering Laboratory of the Enugu State University of Science and Technology, ESUT, Enugu. The test was carried out using the latest version of Instron Universal Testing Machine to determine the compressive strength (N/mm^2), the bio-yield force, the rupture force, the deformation at rupture, stiffness, deformation energy, modulus of deformability and toughness of horse eye bean *(mucuna Sloanei)* under three different moisture contents 11.5%, 13% and 17% (w.b) respectively. The samples were loaded in two (2) different loading positions (longitudinal and lateral loading). The sample where placed in the compressive jaws making sure that the centre of the tool is in alignment with the peak of the curvature of the horse eye bean. Force was applied by turning the load arm of the testing machine with a beam of 2KN and the point of deformation and maximum break (rupture) was noted. It was observed to have a significant drop on the force –deformation graph, which was plotted automatically by the computer using Blue Hill Software thereby recording the force and the corresponding deformation. The results obtained also showed the force deformation curve, indicating bio-yield points, point of rupture which is derived at different loading positions and moisture content. The replication were taken at a maintained means temperature of 29°C. The following parameters were determined from the plotted graph after the experiment; the rupture force, deformation, modulus of deformation, toughness and stiffness.

Toughness: Is the amount of work or energy required to bring about rupture in a material. It was determined by computation of the area under the force – deformation curve before rupture, (Mohsenin, 1986).

$$\text{Toughness} = \frac{\text{Rupture energy}}{\text{volume of material}} \quad - \quad - \quad - \quad (10)$$

Stiffness = The stiffness was determined using equation 11.

$$\text{stiffness} = \frac{\text{Force at material}}{\text{Rupture at material}} \quad - \quad - \quad - \quad (11)$$

As reported by (Maduako and Faborode, 1994),

Deformation Energy was determined using equation 12.

Deformation energy = rupture force x deformation at rupture - - - (12)

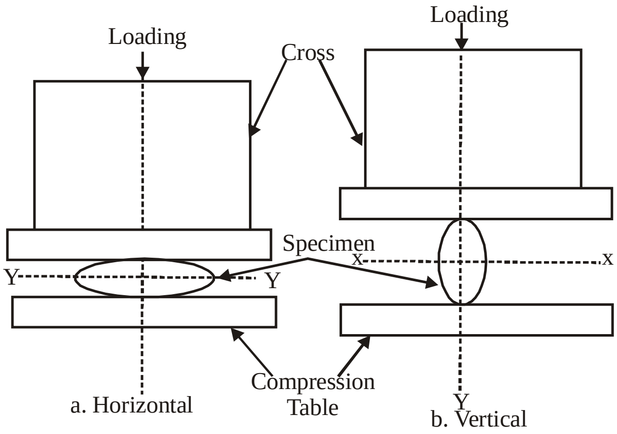

Fig. 3: Block Diagram of Orientations of Horse Eye Bean *(mucuna sloanei)* under Compressive Loading

RESULTS AND DISCUSSIONS

Table 1 shows the mean physical properties of 30 samples of horse eye bean**.** The dimensions increased with an increase in moisture content. The size range at the three mositure contents were 24.98mm to 27.12mm. This shows that there is an increase in the dimensions which contributed to expansion as a result of moisture intake within the horse eye bean.

Also as presented in Table 1, the sphericity, *S*, of the velvet bean (*Mucuna sloanei*) decreased with an increase in moisture content. At 11.5% moisture content, the sphericity increased to 0.882 but decreased to 0.876 at 13% and 0.831 at 17% moisture content. This indicates that relative proportion changes occurred in the dimensions of the horse eye bean (*Mucuna sloanei*) seeds. The finding is similar to that of (Asoegwu et al. 2006) who reported that the sphericity increased with decrease in the seed size with the small sized seeds having the highest sphericity.

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Table 1: The representation of the physical properties of Horse eye bean *(mucuna Sloanei)* at three (3) different moisture contents.

Moisture Content (%)	Major Diameter (mm)	Intermediate Diameter (mm)	Minor Diameter (mm)	Size (mm)	Sphericity	Weight (g)	Volume (mm^3)	Bulk Density (g/mm^3)	Specific Gravity	Surface Area (mm^2)	Aspect ratio
11.5%	28.32 (0.74)	27.60 (1.72)	19.95 (0.75)	24.98 (0.814)	0.882 (1.10)	7.625 (0.593)	20.137 (0.794)	0.378 (0.747)	0.378 (0.747)	598.362 (2.324)	0.974 (2.324)
13%	29.913 (1.717)	29.093 (1.329)	20.66 (2.194)	26.197 (1.52)	0.8757 (0.885)	8.619 (0.735)	21.116 (1.379)	0.408 (0.533)	0.408 (0.533)	664.763 (1.387)	0.973 (0.774)
17%	32.626 (1.25)	30.28 (2.40)	20.18 (1.40)	27.115 (1.18)	0.831 (0.944)	9.203 (0.782)	21.856 (1.30)	0.421 (0.602)	0.421 (0.602)	720.208 (4.52)	0.726 (1.92)

Each value is the mean of 30 test samples; the values in parenthesis are the standard deviation

Also the volume of *Mucuna Sloanei* increases as the moisture content increases. The volume ranges from 20.137 mm^3 to 21.856 mm^3 at the three different moisture contents. Table 1 also showed that the bulk density and specific gravity of the velvet bean varied from 20.137 g/mm^3 to 21.856 g/mm^3 through the three moisture contents of 11.5%, 13% and 17% (db). This result indicates a decrease in bulk density and specific gravity with an increase in moisture content. This implies that there was an increase in weight of the sample owing to the moisture in the horse eye bean which was lower than the volumetric expansion of the bulk agro-material, as reported by (Oduma et al. 2013) for sorghum seeds. Similarly, the surface area of the horse eye bean (*mucuna sloanei*) increased with an increase in moisture content. The surface area increased from 598.362mm^2 at 11.5% moisture content to 664.763mm^2 at 13% and 720.208mm^2 moisture contents (db). This result indicates that the increase in the values may be attributed to their dependence on the size dimensions of the horse eye bean which are similar to the report of (Oluka and Nwuba, 2001) for cowpeas. Table 1 shows that the weight of the seeds increased from 7.625g to 9.203g as moisture content increased from 11.5% to 17% (db). Also, Table 1 showed that the aspect ratio decreased with increase in moisture content with ranges of 0.974 to 0.726.

Table 2 and figures 4 to 7 represent the mechanical properties of horse eye bean (*Mucuna sloanei*) at three different moisture contents (11.5%, 13% and 17% db) and at two loading positions (longitudinal and lateral positions).

Table 2: Represents the mechanical properties of horse eye bean *(Mucuna Sloanei)* at three different moisture contents at two loading positions.

Moisture content (%)	Loading Positions	Compressed Strength (N/mm^2)	Bio-yield Force (N)	Rupture Force (N)	Deformation to rupture (mm)	Stiffness (N/mm)	Deformation Energy (J)	Modulus Deformation (N/mm^2)	Toughness (J/m^2)
11.5%	Longitudinal	8.078	1700	2500	3.00	833.33	7500	1.221	372.448
	Lateral	9.047	2100	2800	3.50	800	9800	1.595	486.666
13%	Longitudinal	4.843	400.0	600.0	5.00	120.00	3000	7.505	142.072
	Lateral	2.457	600.0	800.0	14.00	57.14	11200	3.573	530.403
17%	Longitudinal	1.300	1000	1400.0	10.25	136.583	14350	2.165	656.570
	Lateral	2.221	1500	1700	11.25	151.111	19125	2..885	875.046

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The compressive strength in Table 2 indicates highest at 11.5% moisture content both in lateral and longitudinal loading positions, 9.047(N/mm^2) and 8.078(N/mm^2) respectively, and lowest at 17% moisture content also, both in lateral and longitudinal loading positions 2.221(N/mm^2) and 1.30(N/mm^2) respectively. This indicates that little force is required to cause rupture on the seed (horse eye bean) as reported by (Maduako and Faborode, 1994) on bambara nuts.

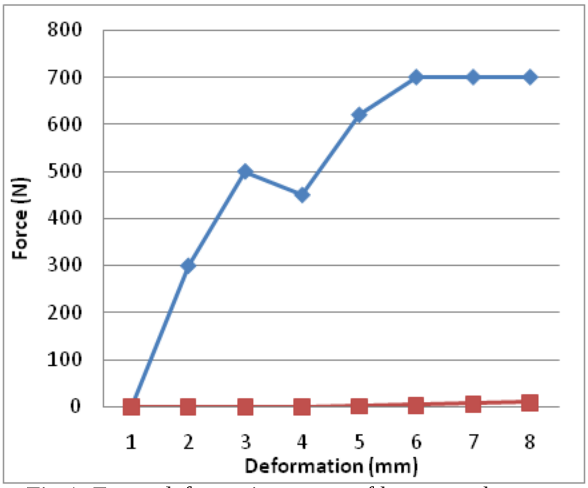

Fig.1: Force-deformation curve of horse eye bean at 11.5% moisture content in vertical loading position.

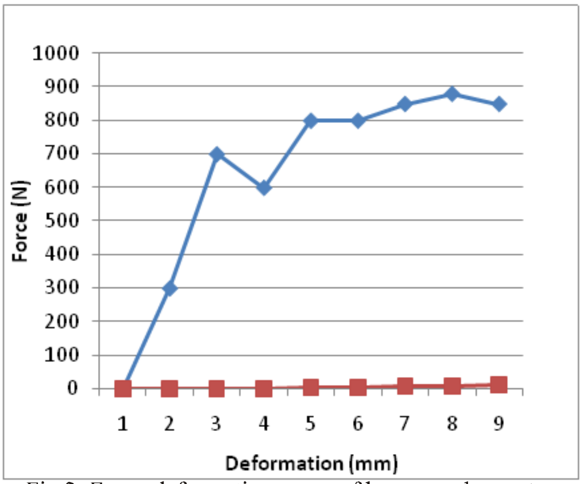

Fig.2: Force-deformation curve of horse eye bean at 11.5% moisture content in longitudinal loading position.

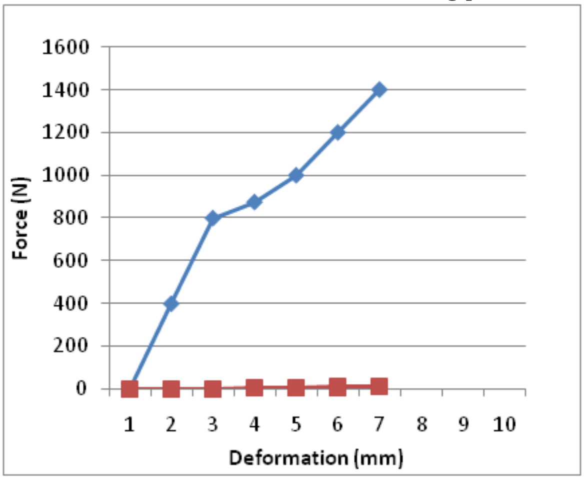

Fig.3: Force-deformation curve of horse eye bean at 13% moisture content in vertical loading position.

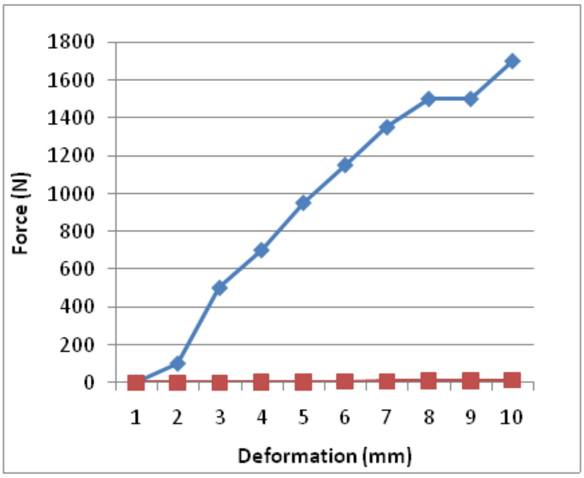

Fig.4: Force-deformation curve of horse eye bean at 13% moisture content in longitudinal loading position.

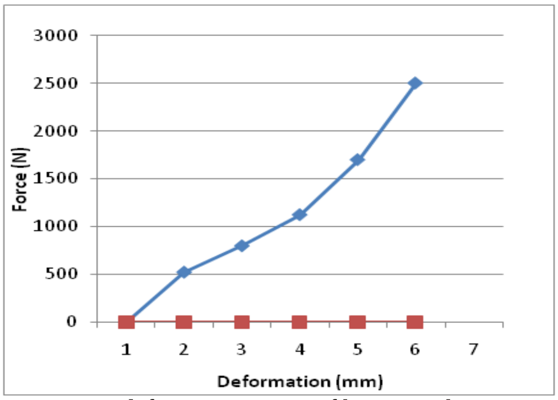

Fig.5: Force-deformation curve of horse eye bean at 17% moisture content in vertical loading position.

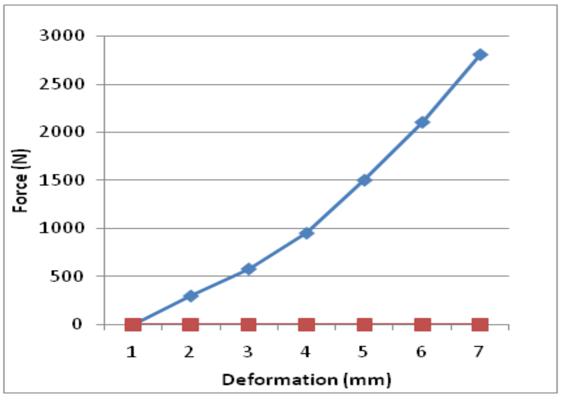

Fig.6: Force-deformation curve of horse eye bean at 17% moisture content in longitudinal loading position.

The Bio-yield force in Table 2 indicate highest at 11.5% moisture content in both longitudinal and lateral loading positions, 1700(N) and 2100(N) respectively and lowest at 13% moisture content also in longitudinal and lateral loading positions, 400(N) and 600(N) respectively.

The rupture force presented in Table 2 increased significantly at 11.5% moisture content in both longitudinal and lateral loading positions as 2500(N) and 2800(N) respectively. At 17% moisture content, the rupture fore in the longitudinal loading is 1400N and 1700N in the lateral loading position, but at 13% moisture content, the rupture forces were recorded lowest as 600N and 800N both in longitudinal and lateral loading positions respectively.

The deformation at rupture with respect to the Table 2 shows that at 11.5% moisture content, the deformation at rupture in the longitudinal loading position is 3.00mm and 3.80mm in the lateral loading position. At 13% moisture content, it shows that the deformation at rupture is 5.00mm in the longitudinal loading position and 14.00mm in the lateral loading position. Then, at 17% moisture content, the deformation at rupture reads 10.25mm in the longitudinal loading position and 11.25mm in the lateral loading position. The stiffness is presented in the Table 2 above that as at 11.5% moisture content; the stiffness is 833.33N/mm in the longitudinal loading and 800N/mm in the lateral loading. At 13% moisture content, the stiffness is 120.00N/mm in the longitudinal loading and 57.14N/mm in the lateral loading position. At 17% moisture content stiffness is 136.585N/m^2 in the longitudinal loading position and 151.111N/mm in the lateral loading position. Deformation energy as recorded in Table 2 is 7500J in the longitudinal loading position and 98003 in the lateral loading position at 11.5% moisture content. At 13% moisture content, the deformation energy is 3000J in the longitudinal loading position and 11200J in the lateral loading position. At 17% it is shown that deformation energy is 14350J in the longitudinal loading and 119125J in the lateral loading position. Furthermore, the modulus of deformability is shown on the Table 2 to be 1.221N/mm^2 in the longitudinal loading position and 1.595N/mm^2 in the lateral loading position at 11.5% moisture content. At 13% moisture content, the deferability is 7.505N/mm^2 at the longitudinal loading and 3.573N/mm^2 in the lateral loading position. At 17% moisture content, the modulus of deformability is 2.165N/mm^2 in the longitudinal loading position and 2.885N/mm^2 in the lateral loading position. The toughness of the horse eye bean *(Mucuna Sloanei*) as shown in the Table 2 above to be 142.072J/m^2 in the longitudinal loading position and 530.403 J/m^3 in the lateral loading position at 13% moisture content. At 11.5% moisture content toughness reads 372.448J/m^3 in the longitudinal loading position and 486.666J/m^3 in the lateral loading position. At 17% moisture content the toughness is 656.570J/m^3 in the longitudinal loading position and 875.046 J/m^3 in the lateral loading position. Therefore, the horse eye bean *(mucuna Sloanei)* is greatly affected by heat (drying). The heat effect affects both the physical and mechanical properties. The moisture content of the horse eye bean also has a significant effect on the physical and mechanical properties of *mucuna sloanei* such that the higher the moisture content, the higher the physical properties which is significant in the following parameter; the geometric mean diameter, sphericity, volume, bulk density, specific gravity and surface area. The 17% moisture content has the highest value. It was also observed that in some cases the increase in moisture content of horse eye bean *(mucuna sloanei)* brings about decrease in the physical properties as it applies to the aspect ratio, the higher the moisture content, the lesser the aspect ratio. Such that the reading was at highest in the 11.5% moisture content. In the mechanical properties it is observed that the three moisture contents 11.5% 13% and 17% (db), the lateral loading position has the highest values at the compressive strength, rupture force, bio-yield, deformation at rupture, energy and toughness but while the values is the longitudinal loading are lesser which indicates that the longitudinal loading position requires less forces and work than that of the lateral loading position but in the stiffness deformability, the lateral loading position leads less in the 13% and 11.5% moisture content and higher in the longitudinal loading positions which shows that the lateral loading position is better than the longitudinal loading position. In general, the parameters of the mechanical properties of *Mucuna Sloanei* will best be processed with the energy application that is within the ranges as reported in the Table 2.

CONCLUSION

Due to the level of water absorption by the horse eye bean, the axial dimension of the horse eye bean (*Mucuna Sloanei*) seeds increased with increase in the moisture content. The physical properties of the horse eye bean (the size, the weight, volume, area, sphericity, bulk density, specific gravity all increased with increase in the moisture content while the aspect ratio decreased with an increase in the moisture content. In the mechanical properties, the toughness of the horse eye bean (*Mucuna Sloanei*) seed increased as the moisture content increased. Therefore, to break the seed, 11.5% moisture content is appropriate. The rupture and bio-yields forces of the horse eye bean increased as the moisture content increase. The result also reveals that the forces at lateral loading position is higher than forces at longitudinal loading position. Therefore, greater force is needed to cause rupture at the lateral loading position than in the longitudinal loading position. This finding agrees with the works and finding of Maduako and Faborode, (1994); and also Oluka and Nwuba, (2001). In respect to this findings, the recommended loading position is the longitudinal loading position. This research results information can be used in the design and development of processing and general handling legume seeds machine and design of the post harvest processing machines.

RECOMMENDATION

It is recommendation that other properties of horse eye bean (*Mucuna Sloanei*) seed such as its thermal and rheological properties are to be determined and changes of these properties are to be examined as a function of the moisture content.

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