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Macmanus Chinenye NDUKWU [1]

MOISTURE DEPENDENT PHYSICAL PROPERTIES OF AFRICAN OIL BEAN SEED

SUMMARY

In this research, some of the physical properties of *P. Macrophylla* seed have been quantified. The physical properties showed variation with the mean value just like all biological materials. The dimension of the African oil bean seed was found to be relatively larger than other seeds. The average geometric, square and arithmetic means of the dimensions ranged from 55.7–56.76mm. The sphericity, roundness factor and roundness ratio were found to be very low (0.75, 0.23 and 0.19, respectively). The specific gravity (1.15) and density (1.04gcm^{-3}) were very close to that of water. The bulk density averaged 1.10gcm^{-3}, which is lower than that of most seeds. The angle of repose and coefficient of static friction were 17.20^{0} and 0.31, respectively.

Key words: Biomaterial, processing, dimension, specific gravity, elliptical

INTRODUCTION

Protein energy deficiency has been reorganized as the most common source of malnutrition in the regions where people depend mainly on a starch-based diet (Igene *et al*., 2005). The major cause of this is the high cost of conventional protein like animal-based protein, which is very expensive, while soybean, which is a major plant-based protein, is becoming expensive due to its diversion to the production of bio fuel. To solve this problem some other alternative plant-based proteins for humans and livestock have been identified as cheap supplements for expensive animal-based protein sources. The African oil bean seed (*Pentaclethra Macrophylla*), which contains 23–28% protein (Barret, 1990), is one of the alternatives to improve the protein content of the family diet. It is a forest tree and belongs to the leguminous family *Mimosoideae* but has no well-known established varieties (Keay, 1989). It is found in the forest zone of Nigeria and the coastal area of West Africa. Enujiugha (2000) established that the seed contains 20 essentials amino acids and essential fatty acids. It is also stated that the oil and carbohydrate contents ranges up to 53.98± 0.99% and 19.6±0.76% dry weight, respectively. *P. macrophylla* can also be used in the area of medicine to treat leprosy (Abbiw, 1990). Sirisombom *et al*. (2007) stated that the parameters of the physical properties of biomaterial are important for effective and efficient design and construction of machines for handling, transportation, processing and storage of the product. According to Koya *et al*.

[1] Macmanus Chinenye Ndukwu (corresponding author: ndukwumcu@gmail.com), Michael Okpara University of Agriculture, Department of Agricultural and Bioresources Engineering, P.M.B. 7267 Umuahia Abia state, Nigeria

(2004) the relative size of a particle in a mixture is important in determining the separation by sorting, while the shape with its coefficient of friction will determine whether the product will slide or roll during motion. Several authors (Olaoye 2000; Oje *et al*., 2001; Baryeh and Mangope, 2003; Koya *et al*., 2004) have described the shape of the biomaterial through the measurement of the linear dimensions that have been used to establish some of the physical characteristics of the material. Koya *et al*. (2004) reported that the design of a machine for shelling agricultural material is influenced by the three axial dimensions, while the geometric mean has been adequate in calculating the Reynolds number, projected area and drag coefficient of food grains. The coefficient of friction or the angle of repose are essential in the design of the storage structures, hoppers, separators, etc., while density is useful in the calculation of aerodynamic drag and the estimation of terminal velocity (Opeke, 1997; Koya *et al*., 2004). Also, the density will determine whether the material will sink or float in liquid media. Therefore, knowledge of these physical properties of this seed is very important and needs to be established and standardized for use in engineering of the planting and processing equipment.

MATERIAL AND METHODS

Materials

A sample size of 200 seeds of the African oil bean *(P. Macrophylla*) was used in this trial. The seeds were stored in a container at room temperature (25^0C) for 24 hours to allow uniform moisture distributions (Ndirika and Oyeleke, 2006) before the experiment began. The principal axis of the seed (minor, major and intermediate diameters) was determined with a digital veneer calliper (SR44 model, Germany) with an accuracy of ±0.02mm (<100mm). The mass was determined with a precision weighing balance by scout pro (SPU 401, China) with an accuracy of ± 0.01g.

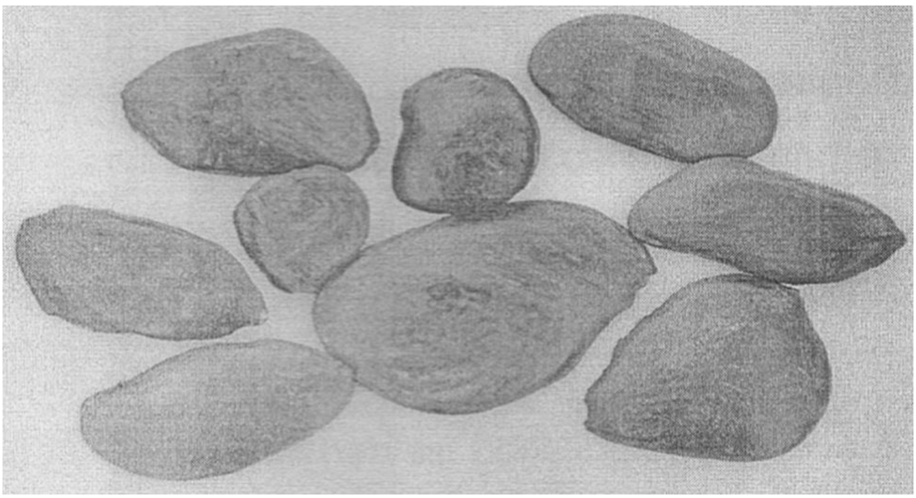


Figure 1. African oil bean seed (*Pentaclethra Macrophylla*)

Experimental procedure

Moisture content

The moisture content (wet bases) of the seed was determined by oven method (UNISCOPE SM 9023, England), dried in the oven at a temperature of 105^0C for 18 hours.

The seed dimensions such as minor, intermediate and major diameters (*L1, L2* and *L3*) respectively were obtained with the use of digital veneer calliper described above. The geometric mean diameter (D_g), Arithmetic mean(A_m), square mean(S_m) and equivalent mean(D_e) diameters was calculated from the equations presented by (Adejumoh *et al.*, 2005) and given below

$$D_g = (l1 * l2 * l3)^{1/3} \quad (1)$$

$$A_m = \frac{l1+l2+l3}{3} \quad (2)$$

$$S_m = \left(\frac{l1l2+l2l3+l1l3}{3}\right)^{1/2} \quad (3)$$

$$D_e = \frac{D_g+A_m+S_m}{3} \quad (4)$$

The method described by (Oje *et al*., 2001) was also used to determine the sphericity, roundness factor and roundness ratio and the equation is given below

$$S = \frac{D_e}{l3} \quad (5)$$

$$R_f = \frac{A_p}{A_c} \quad (6)$$

$$R_r = \frac{r}{R} \quad (7)$$

where: S - sphericity, A_p - largest projected area of the object in the rest position, A_c - area of the smallest circumscribing circle, R_f – roundness factor, R -radius of maximum inscribed circle within the traced outline, r - radius of curvature of the sharpest corner.

The specific gravity was determined with the equation presented by (Nelkon, 2005) below

$$S.G = \frac{weight\ of\ seed\ of\ known\ volume}{weight\ of\ equal\ volume\ of\ water} \quad (8)$$

To determine the angle of repose on plastic and static coefficient of friction, each seed was placed on a plastic rule on a flat table. The plastic rule was tilted until the seed begin to flow freely. The angle the rule makes with the table at the point of free slide is taking as the angle of repose while the tangent to the angle is the static coefficient of friction (Ndirika and Oyeleke, 2005).

The bulk density was calculated with the method described by (Ndirika and Oyeleke, 2005). This was done by packing some seeds in a measuring cylinder. The seed was taped gently to allow the seed to settle into the spaces. The volume occupied by the seed in the cylinder is used to calculate the bulk density as follows

$$B_d = \frac{weight\ of\ packed\ seed}{volume\ occupied\ by\ the\ seed} \quad (9)$$

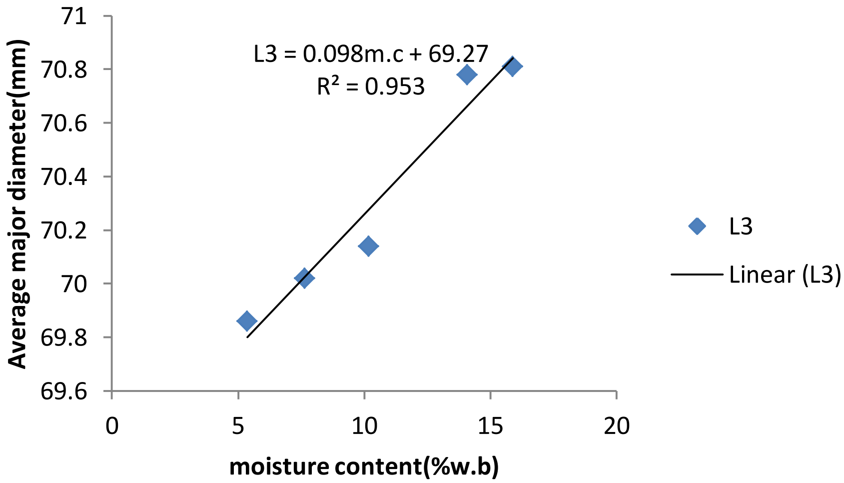
RESULTS AND DISCUSSION

Axial dimensions

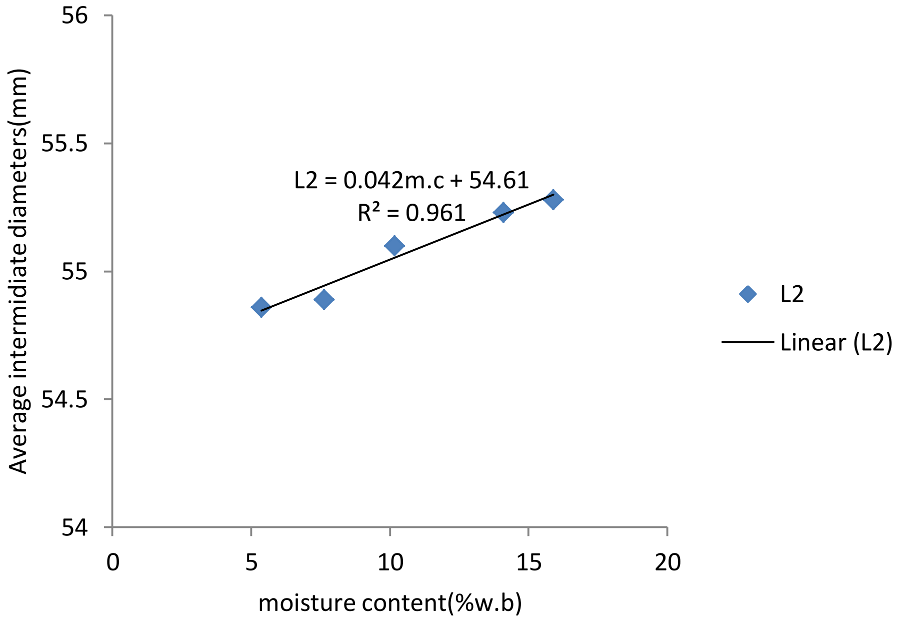
The physical properties of African oil bean are presented in table 1. The axial dimensions are also presented in table 1. These axial dimensions were used to calculate the geometric, arithmetic and square mean diameters respectively. From the table, the range of theses mean were 51.22 to 60.3mm, 50.4 to 60.08mm and 47.21 to 65.25mm for arithmetic, geometric and square mean diameters respectively with mean values of 55.74, 56.25 and 56.76mm respectively. Despite the wide difference between the three dimensions of the bean (minor, intermediate and major diameters), it was found that the three mean (arithmetic, geometric and square mean diameters) diameters of the seed are very close. Therefore for engineering design any of the mean diameters can be used with minimal margin of error. From the result also it can be seen that the variation in thickness is very low and can be assumed that the seed has approximately the same thickness. When the three principal dimensions are compared, there was a 19.9% increase from the minor diameter to the intermediate diameters while there was a 22.06% increase from the intermediate diameters to major diameters at the same moisture content of 14.1%wb. Generally the physical properties showed deviations from the mean value which is common with agricultural materials with the major diameter showing the highest deviation of 12.29 while the least deviation was recorded for coefficient of static friction. The average value reported in this study for the principal dimensions are higher than the other seeds like soybean, groundnut, millet and castor seed (Adejumoh *et al* 2005, Olaoye, 2000)

Table 1: physical properties of African oil bean seed (*P.Macrophylla*) at 14.10 % (w.b)

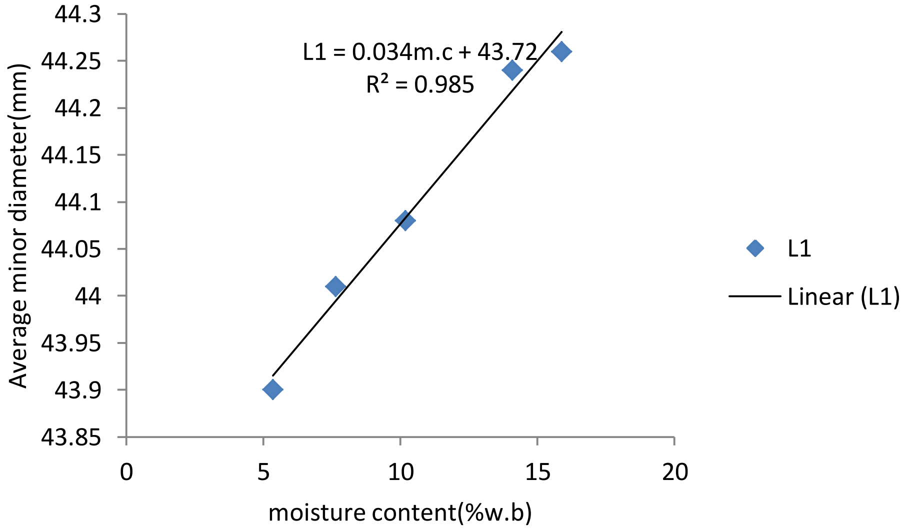
Physical properties (average value)	No. Of samples	Mean value	Standard deviation
Major diameter (mm)	100	70.87	12.29
Intermediate diameter (mm)	100	55.23	9.60
Minor diameter (mm)	100	44.24	5.41
Thickness (mm)	100	12.61	1.77
Arithmetic mean diameter (mm)	100	56.76	5.54
Geometric mean diameter (mm)	100	55.74	5.34
Square mean diameter (mm)	100	56.25	9.04
Equivalent diameter (mm)	100	56.25	5.22
Roundness factor	100	0.21	0.03
Roundness ratio	100	0.19	0.05
Seed weight (g)	100	16.48	4.22
Seed volume (cm^3)	100	15.92	4.56
Seed density (gcm^{-3})	100	1.04	0.02
Bulk density (gcm^{-3})	58	1.10	0.12
Specific gravity	50	1.15	0.16
Angle of repose (^{0})	50	17.20	2.85
Coefficient of static friction.	50	0.310	0.05
Sphericity	100	0.75	0.14
Moisture content (% wb)	15	14.10	



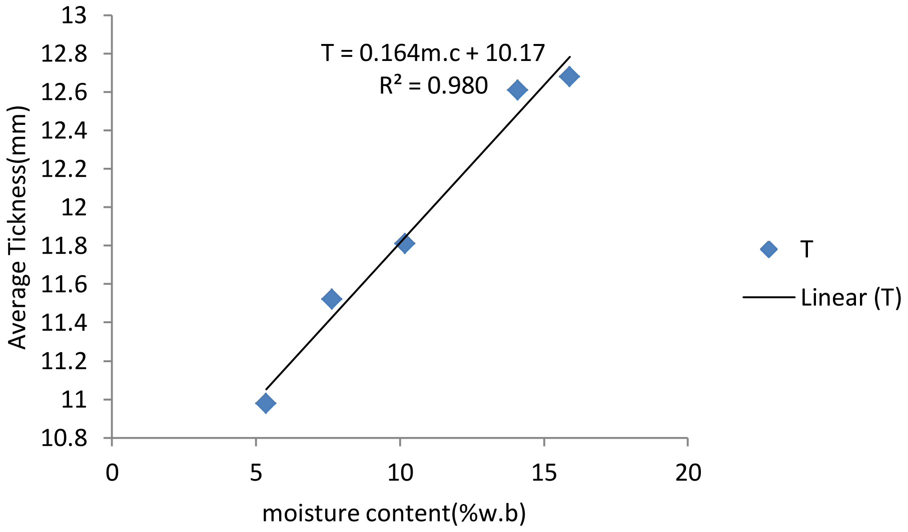
Graphic 1. Effect of moisture content on major diameter of P. *Macrophylla*



Graphic 2: Effect of moisture content on intermediate diameter of P. *Macrophylla*



Graphic 3. Effect of moisture content on minor diameter of P. *Macrophylla*



Graphic 4. Effect of moisture content on thickness of P. *Macrophylla*

Roundness factor, roundness ratio and sphericity

The mean values of roundness factor, roundness ratio and sphericity (0.21, 0.19 and 0.75) are low which implies that the seed cannot roll. This may be due to the shape of the seed which is flat and approximately elliptical. Since the sphericity is a function of the geometric mean and major diameters it will also increase with increase in moisture content like the major diameters.

Specific gravity and density

The specific gravity (1.15) and density (1.04) of the seed is very close to that of water which explains why the seed cannot completely be submerged in water at room temperature and this property is useful in designing the cleaning and washing machine as well as the fermentation process. The value of density obtained is lower than some biomaterials like durra specie of palm nut (1.16) and Kano white variety of Bambara groundnut (1.45) (Adejumoh *et al*. 2005, Koya *et al*. 2004). The value of the bulk density was gotten as $1.10 gcm^{-3}$. The low value of the bulk density could be attributed to the large size of the seed making few of them to occupy a large volume. This value is very much lower than that of some agricultural product like palm nuts, groundnuts, castor seeds and pearl millet (Olaoye, 2000, Koya *et al*. 2004, Adejumoh *et al*. 2005, Jain and Bal 1997)

Coefficient of static friction and angle of repose

The angle of repose on plastic averaged 17.20 ± 2.85^0 while the coefficient of static friction ranged to 0.31 ± 0.05 which implies that, the seed can slide very easily with a small angle of tilt. The low value might be due to the smoothness of the plastic surface coupled with the smoothness of the shell. This value is closer to that gotten by (Adejumoh *et al*. 2005) on fibre glass for the palm nuts but lower than those gotten by (Laskowsky and Skonecki 1997) on three varieties of crushed legumes of horse, lupine and vetch bean ($36.2\text{-}43.2^0$). This is an important parameter in hopper design.

CONCLUSIONS

The physical properties of *P. Macrophylla* have been quantified. From the results of this study, the following conclusions can be made:

1. The physical properties show variation in the mean value, just like all biological materials.
2. The dimensions of the African oil bean are fairly larger than other seeds and this information will be useful in engineering design.
3. Due to the low values of the sphericity, roundness factor and roundness ratio, it can be concluded that the seed cannot roll.
4. The small value of the angle of repose and coefficient of static friction implies that with a low tilt angle the seed can slide freely, which will be very useful in hopper design.
5. The bulk and true density is smaller than that of some seeds and closer to the density of water, which will be useful in the boiling and fermentation processes of the seed.

REFERENCES

Abbiw, D. K. (1990): Useful plants of Ghana, Intermediate Technology publications and the Royal Botanic Gardens Kew, London, S.154–157.

Adejumoh O.I, Alfa A.A, Muhmmed. A (2005): Physical properties of Kano white variety of Bambara groundnut. Proceedings of Nigerian Institution of Agricultural Engineering. Vol 27 pp 203-210.

Asoegwu S. N. (2006): physical properties of oil bean seed (pentaclathra macrophylla) *Agricultural Engineering international the CIGR journal vol 111*

Baryeh A.E, Mangope B.K, (2003): Some physical properties of QP-38 variety of pigeon pea *Journal of food Engineering 56(1)59-65.*

Barrett, R.P. 1990): Legume species as leaf vegetables. p. 391-396 www.hort.purdue.edu

Igene. J.O, Salami. L.I, Nkama. I, Negbenebor,CA., Obinomen S.A, (2005): Physiochemicalproperties of cassava starch- based fish and beef crackers. *Journal of raw material research 2(1) pp 26-33.*

Enujiugha, V. N, (2000): Nutrient changes during the fermentation of African oil bean (pentaclthra macrophylla benth) seeds. *Pakistan journal of nutrition 2(5): 320-323*

Jain R.K and Bal S. (1997): Physical properties of pearl millet. *Journal of agricultural engineering research,66:85-91*

Koya. A, Idowu. A, Faborede. M.O. (2004): Some properties of palm kernel and shell relevant in nut cracking and product separation. *Journal of agricultural engineering and technology volume 12*

Keay W. R. (1989): Flora of west Tropical Africa, Nigerian Trees.Ed 2.Millbank, London

Krause, J.P, Mothes, R. and Schwenke, K.D. (1996): Some physiochemical and interfacial properties of native and acctylated legume from fabaceae bean (Vicia faba L.) J*ournal of Agricultural Food Chemical* 44: 429-437.

Laskowsky.J and Skonecki.S (1997). Influence of moisture on the physical properties and parameters of compression process of lgumes seed *int agrophysics* (11) 245-256

Ndirika, V.I.O. and Oyeleke O.O. (2006): Determination of selected physical properties and their relationship with moisture content for millet (pennisetum glaycum). *Applied Engineering in Agriculture*, 22(2), 291-297

Nelkon, M.(2005): Principles of physics for senior secondary schools revised edition Heinemann London

Oje, K., Alonge, A.F., Adigun Y.J. (2001): Some engineering properties of shear nut relevantto mechanical processing. *Ife journal of technology 10(2):17-20*.

Olaoye, J.O. (2000). Some physical properties of castor nut relevant to the design of processing equipment. *Journal of Agricultural Engineering Research,77(1) 113-118*

Opeke, L.K. (1997): Tropical tree crops. John Willy and Sons Chischester

Sirisombom, P. Kitchaiya, T. Phoslpho, W. Mahuttanyavanitch (2007): Physical and mechanical properties of Jastropha curcas. L. fruits, nuts and kernels. *Biosystemengineering 97; 201-207.*

Macmanus Chinenye NDUKWU

FIZIČKE OSOBINE SJEMENA AFRIČKE ULJARICE PENTACLATHRA MACROPHYLLA

SAŽETAK

U ovom istraživanju izvršena je kvantifikacije određenih fizičkih osobina *P. Macrophylla*. Fizičke osobine su pokazale određeno variranje u odnosu na aritmetičku sredinu, što je sklučaj sa svim biološkim materijalima. Dimenzije sjemena ove afričke uljarice je relativno veće od ostalih sjemena. Prosječna geometrijska, kvadratna i aritmetička sredina dimenzija kretala se od 55,7-56,76mm. Vrijednosti seričnosti, faktora zaobljenja i odnosa zaobljenosti bili su veoma niski (0,75; 0,23 i 0,19). Specifična težina (1,15) i gustina (1,04gcm^{-3}), veoma su blizu vrijednosti vode. Zapreminska gustina je u prosjeku iznosila 1.10gcm^{-3}što je niže nego za većinu sjemena. Ugao nasipanja i koeficijent statičkog trenja iznosili su 17.20^{0}, odnosno 0,31.

Ključne riječi: Biomaterijal, prerada, dimenzija, specifična težina, elipsoid