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Determination of the physical and frictional properties suitable for optimum kernel recovery in the dry-cracking of dika (*Irvingia)* nuts

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Abstract

The nut cracking process is labour intensive and usually a large percentage of the kernels are broken which tends to reduce its market value. Therefore, determination of the physical and frictional properties suitable to explore the possibility of developing their handling and processing equipment was investigated at moisture content 8.1, 9.7, 10.2, 11.0 and 11.4% at wet basis. Venier caliper was used to determine the seed dimension. The aspect ratio, seed surface area, seed volume, bulk density, true density and angle of repose were investigated. The results shows that its major, intermediate and minor diameter ranged from 3.60cm-5.0cm, 4.50cm-2.70cm and 3.20cm-2.0cm respectively, its seed volume ranged from 8.55-26.86cm^3, surface area ranged from 19.11-47.94cm^2 and equivalent diameter ranged from 4.22-8.49cm and true and bulky density polynomially increased from 3.64g/cm^2 – 4.33g/cm^2, 10.31g/cm^2-12.26 g/cm^2 respectively and was observed to increase with an increase in moisture content (wet basis) and its relevant regression equations were developed. The frictional properties were also studied, it was observed that the coefficient of static friction increased from 0.60-0.90 (plywood), 0.50-0.82 (mild steel), 0.37-0.70 (glass), 0.30 to 0.64 (plastic), amongst which plywood gives the highest range of value which implies that plywood constructed machine required higher power closely followed by mild steel. Conclusively, the results of this study are recommended for use by designers to qualitatively design effective and efficient machines for processing, drying, handling operations, storage of Dika seeds and machines for cracking kernel.

Keywords: *Irvingia* nut, regression equation, moisture content, physical properties, mechanical properties

Introduction

Irvingia Gabonensis is a species of African trees in the genus Irvingia, sometimes known by the common names wild mango, African mango, bush mango, Dika or Ogbono. They bear edible mango-like fruits, and are especially valued for their fat and protein-rich nuts. The wild mango (Irvingia spp.), also called Dika tree, is classified in the Irvingiacea family of plants and is a commercially and socially important fruit tree of the West and Central Africa. The tree has been identified as one of the most important fruit trees for domestication in the region, because of its relative importance to the food industry [1, 2, 3]. Dika fruit is a drupe with a thin epicarp, a soft fleshy thick mesocarp and a hard stony endocarp encasing a soft dicotyledonous kernel. The longitudinal section is as shown in figure 1.1

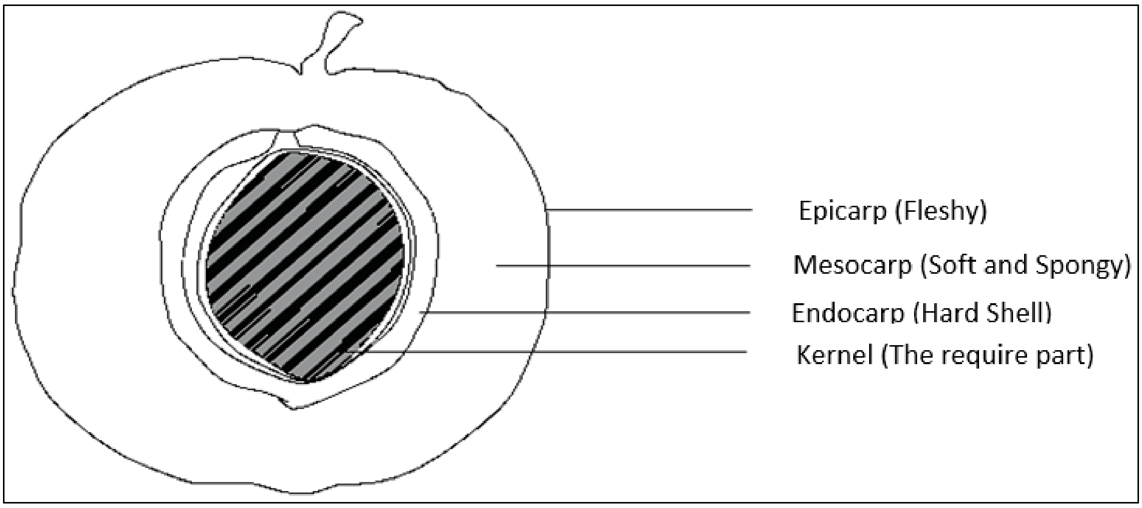

Fig 1: Longitudinal Section of an Irvingia Fruit

The kernel, with about 62.8% lipids, 19.7% carbohydrates, 8.9% protein, 5.3% dietary fibre and 3.2% ash [4, 5] has been incorporated in human nutrLition for controlling dietary lipids and weight gain [2, 6, 7]. Dika kernels are widely marketed locally, nationally and between countries in West Africa, especially for their food thickening properties. The economic importance of the kernel is further strengthened by its use as a pharmaceutical binder and a base material in the manufacture of soap, cosmetics, confectionary and edible fats [8, 9, 10]. The dika tree (Irvingiacea spp) is very valuable for its edible yellow mango-like fruit and the termite-resistant-wood [9]. The tree grows naturally in the humid, lowland forests of tropical Africa but is widely planted in Central and Western Africa [3].

The major limitation and problem in the exploitation of dika kernel is the drudgery involved in its extraction. In rural areas mostly women who do most of the cracking hold the wet or dried one at a time, against a hard/ stony surface to split it open with a machete along its natural line of cleavage or when sufficiently dried Irvingia nut takers a longer time to dry for complete separation of the nut and kernel because of its semi-stony shell unlike the palm nut, African nut meg, cashew nut, groundnut etc which tends to dry when exposed directly to the sun within two or three days. recently researchers have developed cracking machines but could not attain 100% cracking efficiency due to the fact that the kernel and the nut has not been separated by drying before cracking took place.

This research covered the analysis of some physical properties (necessary for the design of selective kernel separator, seed handling machine parts, machines and equipments for grading, sorting, cleaning, dehulling and packaging.) and the frictional properties (necessary for defining the flowability of the kernels thereby aiding in proper design decision making regards to seed conveyance) of Dikanut *(Irvingiagabomosis*) at a moisture content range of 8.1% to 11.4% (wet basis).

Materials and Methods

Experimental Design

1. Materials Used for Drying the Irvingia Nut

Bulk quantity of skin dried harvested dika nut was obtained from Swali market in Bayelsa State, Nigeria. The nuts were manually cleaned. The apparatus/ equipment used for this work during drying were obtained from the Department of Agricultural and Environmental Engineering laboratory (Processing Lab), Niger Delta University. The equipment was; Vernier Caliper, Air oven, mental dishes, weighing balance and Intron universal testing machine.

2. Determination of Moisture Content:

Fifteen (15) samples of Irvi**n**gia nut initially weighed to be 8.1, 9.7, 10.2, 11.0, and 11.4 and was grouped into 3 (three) and then dried in an oven set at 100^0C, 125^0C, and 150^0C. The samples were weighed before drying and the weight reduction was observed every 10minutes using electronic weighing balance until the seed is completely separated from the shell. The loss of weight was expressed as a percentage of the initial weight was taken as the moisture content of the samples; the moisture content was calculated using

$$M_{cwb} = \frac{(wi - wf)}{wi} \times 100 \qquad 1$$

Where M_{cwb} is he moisture content (%) wet basis, W_i is initial weight of sample (g) and w_f is final oven dried weight of sample (g)

3. Seed Dimension.

The principal dimensions (l_1, l_2, and, l_3) of the seed were determined using a Venier Caliper with an accuracy of 0.02mm.

3.1 The arithmetic mean diameter (F_1), geometric mean diameter (F_2), Square mean diameter (F_3), equivalent diameter (D_e)

Were determined respectively using the formulae by [11].

$$F_1 = \frac{(L1 + L2 + L3)}{3} \qquad 2$$

$$F_2 = (L_1 \times L_2 \times L_3)^{1/3} \qquad 3$$

$$F_3 = \frac{L1L2 + L2L3 + L3L1}{3} \qquad 4$$

$$De=\frac{(F1+F2+F3)}{3} \qquad 5$$

where L_1, L_2, and L_3 = major, intermediate, and minor diameters

3.2 The aspect Ratio. (Ar)

Were determine by using formulae by [12].

$$A_r=\frac{L1}{L2} \qquad 6$$

3.3 Seed Surface Area (A_s) and Seed Volume

Were calculated using the following relationships [13].

$$A_s=\frac{\pi BL12}{2L1-B} \qquad 7$$

$$V=\frac{\pi B2L12}{6(2L1-3)} \qquad 8$$

Where $B = (L_1L_3)^{0.5}$

And □=Mathematical constant

3.4 Bulk Density

This is the ratio of the mass of the nuts to its total volume was determine filling up a 600ml beaker with samples, striking off the top level without seed being compacted in any way weighing the set up and subtracting the weight of the beaker Equation (9) was used [13, 14]

$$p_b=\frac{Bsam}{Bv} \qquad 9$$

where Bsam is the bulk nut mass and Bv is the beaker volume

3.5 True density (P_t)

True density was determined using toluene displacement method, toluene was used in place of water. 500ml of toluene was put in 100ml graduated measuring cylinder. Seeds from each batch were first weighed using an electronic weighing balance and then immersed in toluene in five replicates. The amount of displacement was recorded as the volume. Hence true density was obtained using 10

$$P_t=\frac{weight\ of\ seed}{v2-v1} \qquad 10$$

Where V_2= Final Volume, V_1=Initial Volume

3.6 Porosity (ε)

Porosity determine as a function of the volume fraction ($F_y=P_b/P_t$). The porosity expressed in percentage was calculated using equation [11, 14, 15, 16, 17]

$$\varepsilon=(1-f_y)\times 100\% \qquad 11$$

3.7 Sphericity(ϕ)

This calculated using Equation [12, 18, 19]

$$\phi=\frac{(LWT)1/3}{L} \qquad 12$$

3.8 Angle of Repose (ϕ_r)

This determined at different moisture contents using a square box method. In this method, a specially constructed square box with a removable front cover was used. The box was filled with the seeds from each batch; the front was then quickly removed, allowing the seeds to flow to its natural angle. The height (H) of the seeds was measured together as well as the length of spread (L) and the expression below [20] used to determine the angle of repose for the different moisture contents:

$$\phi r = \tan^{-1}\left(\frac{H}{L}\right) \qquad 13$$

Where H= maximum height of the seeds in mm; L= spread length in mm

4 Frictional Properties

4.1 Determination of Static Coefficient of Friction

The static coefficient of friction for various sample batches was determine against three (3) different structural materials, steel metal plate, plywood, plastic and fibre glass. A carton of St. Louis sugar dimension was filled up to the brim with the samples from each batch at a time and placed inverted on the surface lying on the adjustable tilling table. The carton was slightly removed so as to prevent the edges from touching the surface of the structural material. The entire set up was raised gradually using the tiled table screw device until the inverted carton of samples started to slide down and the angle of tilt ($\propto$) was read off using a protractor equation (14) was then used to determine the values of the static coefficient of friction (μ) on the structural surfaces at different moisture content levels [21, 22].

$$\mu = \tan\alpha \qquad 14$$

Results and Discussions

1. Physical Properties

The nuts were grouped into five (5) batches of moisture content values of 8.1, 9.7, 10.2, 11.0 and 12.0 (wet basis). The average dimensions of volume, major, intermediate, and minor diameters of each batch were determined by taking the average of the replicate values as shows in Table 3.1.

Table 1: Batch average of Dimensions

MC	L1(cm)	L2 (cm)	L3 (cm)	F1 (cm)	F2 (cm)	F3(cm)
8.1	3.60	2.70	2.0	2.77	2.44	7.44
9.7	3.95	3.10	2.29	3.11	2.72	9.23
10.2	4.10	3.50	2.46	3.35	2.91	11.07
11.0	4.50	3.50	3.00	3.67	3.18	13.25
11.4	5.0	4.50	3.20	4.23	3.61	17.63

2. Seed Dimensions

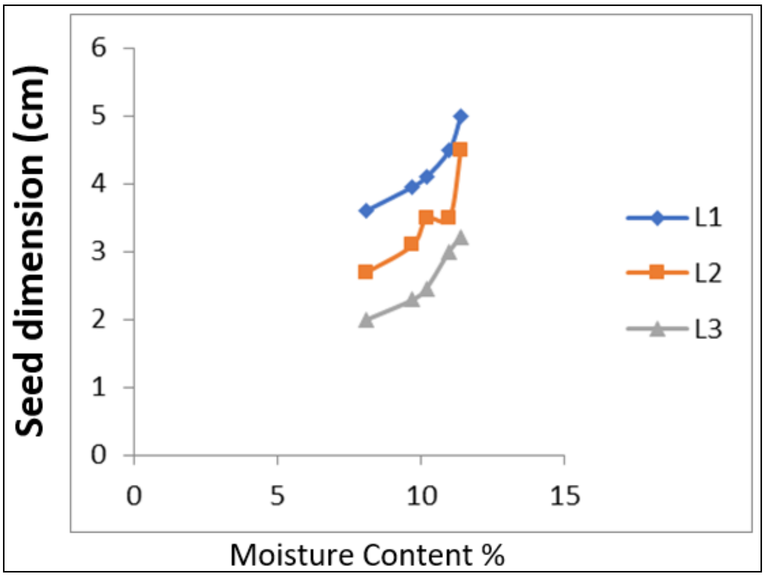

Fig 1: Effect of moisture content on seed dimensions

The average major, intermediate and minor diameters for moisture content ranges from 8.1% to 11.4% in wet basis. They were observed to vary from 3.60cm to 5.0cm, 2.7cm to 4.50cm, 2.0cm to 3.20cm respectively. Fig.1 this showed the diameter of the seed they all increased nonlinearly as moisture content increased. The following regression models (Equation 3.1-3.3) were developed for the effect of moisture content on seeds dimension. The linear relationship is recommended as the best that relates these properties to moisture content. [12, 13, 14, 23] all posited linear response of seed dimensions to moisture increase

Table 2

$L1= 1149.4M^2 - 186.82M + 9.59$	$R^2 = 0.9952$	3.1
$L2= 1317.5M^2 - 217.21M + 12.563$	$R^2 = 0.9807$	3.2
$L3 = 1432M^2 - 232.69M + 12.174$	$R^2 = 0.9504$	3.3

3. Seed Volume and Surface Area

Table 3: Effect of moisture content on seed volume and surface area

MC LEVEL	V(cm^3)	As (cm^2)
8.1%	8.55	19.11
9.7%	11.80	24.88
10.2%	14.52	27.97
11.0%	18.56	35.35
11.4%	26.86	47.94

Table 3. shows the behaviour of seed volume and seed surface area with respect to changes in moisture content levels. Seed surface area ranged from 19.11cm^2 to 47.98cm^2 and seed volume between 8.55cm^3 to 26.86cm^3. The following Polynomial regression models 3.4 and 3.5

Table 4

$As= 17198M^2-2721M+126.74$	$(R^2=0.9997)$	3.4
$V=11146M^2-1773.5M+79.083$	$(R^2=0.9987)$	3.5

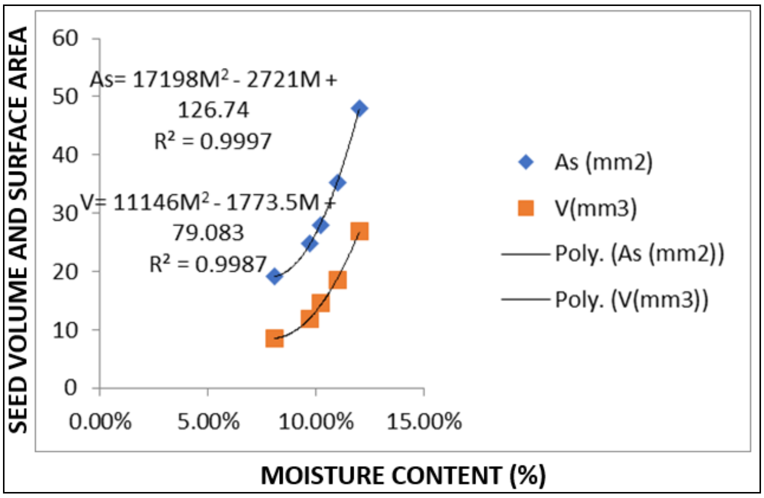

Fig 2: Effect of moisture on seed volume and surface area

From the above figure 2, seed volume and surface area increased polynomially as moisture content increases. This is dissimilar to the results of some researchers like [12] who suggested a linear increase of seed volume and seed area as moisture content of corn increased [24].

4. Equivalent Diameter

Table 5: Effect of moisture content on equivalent diameter

MC LEVEL (%)	De (cm)
8..1	4.22
9.7	5.09
10.2	5.78
11.0	6.7
11.4	8.49

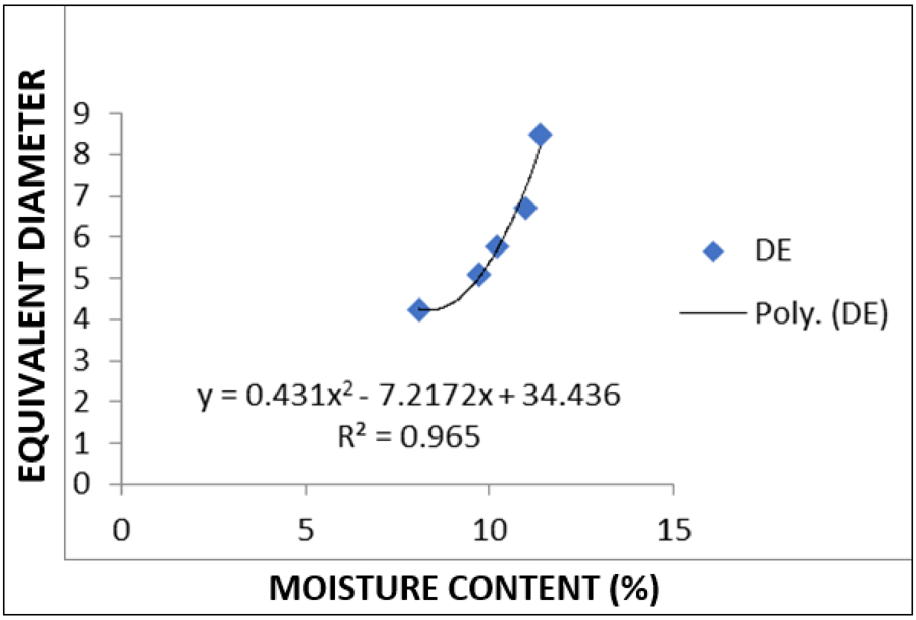

Fig 3: Effect of moisture content on equivalent diameter:

The equivalent diameter in Table 3 and figure 3 was seen to exhibit a polynomial increase as moisture content increase as shown in (equation 3. 6).

Table 6

$DE = 0.431M^2 - 7.2172M + 34.436$	$R^2 = 0.965$	3.6

5. Aspect Ratio and Sphericity

There was a gradual polynomial decrease of seed sphericity as moisture increase as shown in Table 4 below. This indicates that seed is a little bit close to being a sphere as the principle dimensions of the seed increase with the respect to moisture content. On the other hand, aspect ratio showed a third polynomial increasing trend. The following Regression models were 3.7 and 3.8 developed to this effect.

Table 7

$A_r = 0.0008x^2 + 0.0246x + 0.4919$	$R^2 = 0.9137$	3.7
$\emptyset = -0.0003x^2 - 0.0032x + 0.9338$	$R^2 = 0.8921$	3.8

Table 8: Effect of moisture content on Aspect Ratio and Sphericity.

MC LEVEL	A_r	$\emptyset$
8.1	0.75	0.75
9.7	0.78	0.77
10.2	0.85	0.80
11.0	0.87	0.84
12.0	0.90	0.85

[12] suggested a linear for the aspect ratio and sphericity of corns [13, 24]. suggested a linear behaviour too for the sphericity of parkia fillicoidea specie of locust bean and paddy grain respectively. Similar trends have been reported by [25] for African oil bean seed [26]. reported a quadratic polynomial regression model for the effect of moisture on the sphericity of Roselle seeds, while [25] suggested a power model for African breadfruit seeds.

6. Angle of Repose

Table 9: Effect of Moisture Content on Angle of Repose

MC	θr
8.1	22.00
9.7	26.00
10.2	29.00
11.0	33.00
12.0	34.00

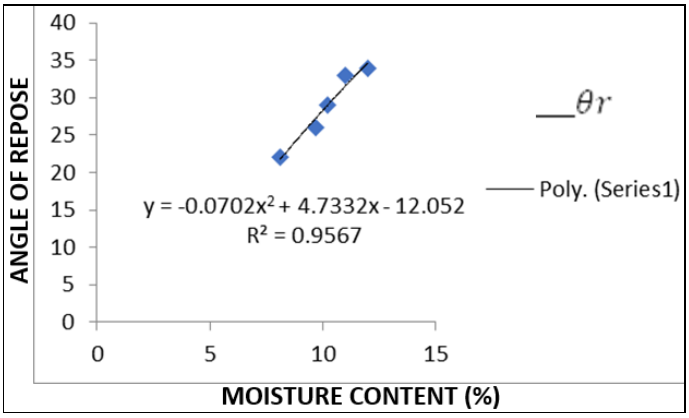

Fig 5: Effect of moisture content on Angle of repose

The angle of repose (ϕ_r) of Dika nut seeds increased from 22.00° to 34.00° as the moisture content increase from 8.1% to 11.4% wet basis. This may be due to the fact that an increase in moisture content increases the cohesion between the seeds. In terms of flowability, the seeds are heavier and the inertia to move is increase. The increase in resistance to flow prevents seeds from sliding on each, thereby increasing the angle of repose of the seed. As shows in figure 5. [27], for green grain, [28] lentil seeds and [29] for dried pomegranate seeds. Equation 3.9 was developed

Table 10

$\phi r = -0.0702x^2 + 4.7332x - 12.052$	$R^2 = 0.9567$	3.9

7. Density

Table 11: Effect of moisture content on Bulk and True density

Moisture content (%)	Bulk density g/cm^2	True density g/cm^2
8.1	3.64	10.31
9.7	3.80	10.72
10.2	4.10	11.0
11.0	4.22	11.63
12.0	4.33	12.26

Table 12

Bulk density= $0.0919M^2-1.3306M+15.042$	$R^2=0.9923$	3.10
True density= $0.0001M^2+0.1933M+2.0617$	$R^2=0.9234$	3.11

From figure 6 bulk density increases polynomially from $3.64g/cm^2$ to $4.33g/cm^2$ and true density also increase polynomially from $10.31g/cm^2$ to $12.26g/cm^2$. A linear behaviour was suggested by Amin *et al*. (2004) for both the bulk and true densities of lentil seeds with respect to moisture content variance [30]. suggested an average safe storage density of yam bean to be $1.01779g/cm^2$ and $1.0036g/cm^3$ respectively for true and bulk densities [27]. posited a linear increase in density of $807kg/m^3$ to $708kg/m^3$ bulk density and $1363kg/m^3$ to $1292kg/m^3$ (true density) for green gram. Equation (3.10) and (3.11) are regression models developed.

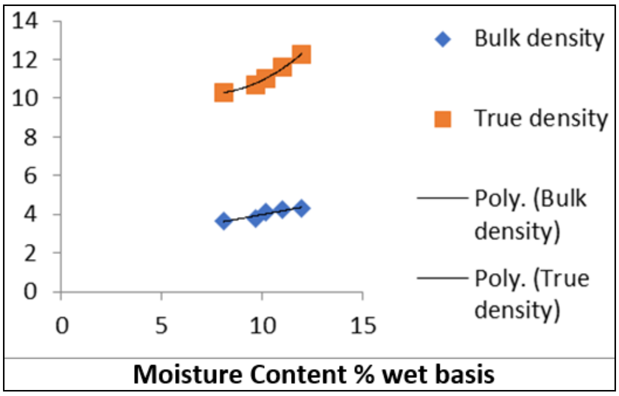

Fig 6: Effect of moisture content on Bulk density and True density

8. Frictional Properties

Table 7: Effect of moisture content on static coefficient of friction

MC %	Plywood	Mild steel	Plastic	Glass
8.1	0.60	0.50	0.30	0.37
9.7	0.68	0.56	0.35	0.41
10.2	0.	0.71	0.47	0.58
11.0	0.85	0.78	0.58	0.65
11.4	0.92	0.82	0.64	0.70

Plywood = $0.0284M^2 - 0.4561M + 2.4336$	$R^2 = 0.9998$	3.12
Mild steel = $0.028M^2 - 0.4387M + 2.0165$	$R^2 = 0.9878$	3.13
Plastic = $0.019M^2 - 0.2671M + 1.411$	$R^2 = 0.9378$	3.14
Fibre glass = $0.0252M^2 - 0.3844M + 1.8243$	$R^2 = 0.923$	3.15

Some frictional properties of Dikanut which were studied as a function of moisture content gave the following results which define seed flowability as a function of moisture content. The static coefficients of friction on the four different surfaces and at five different moisture content levels are shown in Table 7 above. It can be observed that the static coefficient of friction for all the structural surfaces tested in the experiment had a polynomial increase as moisture increases, with plywood having the highest coefficient by mild steel and plastic lastly glass. These are given in equation 3.12 to 3.15 The material grains of plywood are rougher than those of mild steel, plastic and glass, hence, the reasons for the high coefficient of static friction with plywood. Therefore, the power demand of processing machines involving friction increase with increase in moisture content also with increase in coefficient of static friction. This implies that in plywood constructed machines, higher power will be required than in similar machine constructed with mild steel [30]. posited linear increase for average value of coefficient of static friction of African yam bean from aluminium to asbestos than plywood at a safe moisture content [20]. suggested a linear increase too for oil bean seeds using, plywood, mild steel, fibreglass and plastic with a simultaneous increase in moisture content and equally posted that the plywood gave the highest values [29]. posted a linear increase too for pomegranate seeds for various structural surfaces with plywood giving the highest values.

Conclusion

Dika nut is fairly spherical and the embedded kernel is approximately ellipsoidal, but the nut and kernel sizes are independent. All properties studied were found to have a polynomial response to moisture content increase within the moisture content range studied (8.1, 9.7, 10.2, 11.0 and 12.0% at wet basis). The Irvingia nuts dimensions increased from 3.60 to 50.0cm, 2.70 to 4.50cm, 2.0 to 3.20cm and 2.65 to 4.10cm for major, intermediate, minor and equivalent diameters respectively as moisture increased. The seed volume and surface area increased from 8.55 to 26.86 cm^3 and 19.11 to 47.94 $cm^{2\ in}$ relation to moisture content. Bulk density and true density increased from 3.64g/cm^3 to 4.33g/cm^3, and 10.31g/cm^3 to 12.26 g/cm^3 respectively with increase in the moisture range tested. Aspect ratio and sphericity and porosity increased from 0.75 to 0.90; 0.89 to 0.86; 0.41 to 0.61 respectively within the moisture content range studied. Angle of ratio increase from 22.0^0 to 33.0^0 while static coefficient of friction were 0.60 to 0.92 (plywood), 0.50 to 0.82 (mild steel), 0.37 to 0.70 (glass), 0.30 to 0.64 (plastic) with plywood giving the highest range of value. Based on the observation during the experiment, the following recommendations are provided to and any further work on this research.

1. The relevant data obtained is useful for the design and development of machines for cracking kernel
2. The results of this study are recommended for use by designers to qualitatively design effective and efficient machines for processing, drying, handling operations and storage of Dika seeds.

References

1. Adebayo-Tayo BC, Onilude AA, Ogunjobi AA, Gbolagade JS, Oladapo MO. Detection of fungi and alfatoxin in shelved bush mango seeds (Irvingia spp.) stored for sale in Uyo, *Nigeria. African J. Biotech*,2006:5(19):1729-1732.
2. Leakey RRB, Greenwell P, Hall MN, Atangana AR, Usoro C, Anegbeh PO *et al.* Domestication of Irvingia gabonensis: 4. Tree-to-tree variation in food-thickening properties and in fat and protein contents of dika nut. Food Chemistry,2005:90(3):365-378.
3. White L, Abernethy K. Guide de la végétation de la Réserve de la Lopé, Gabon.ÉCOFACPress, Dakar, Gabon, 1996.
4. Ejiofor MAN. Nutritional values of Ogbono (Irvingia gabonensis var. excelsa). International Centre for Research in Agroforestry and InternationaI Institute of Tropical, 1994.
5. Osagie AU, Odutuga AA. Chemical characterization and edibility of the oil extracted from dika kernel. *Nigerian Journal of Nutritional Science,* Patent storm. 2008. Lever actuated nutcracker. US Patent 4843715, 1986*:*1(1):33-36.

6. Agbor LON. Marketing trends and potentials for Irvingia gabonensis products in Nigeria. Proc. ICRAF-IITA Conf. Irvingia gabonensis, Ibadan, Nigeria, 1994.
7. Ngodi JL, Oben JE, Minka SR. The effect of Irvingia gabonensis seeds on body weight and blood lipids of obese subjects in Cameroon. Lipids Health Discover,2005:4(12).
8. Agbor LON. Marketing trends and potentials for Irvingia gabonensis products in Nigeria. Proc. ICRAF-IITA Conf. Irvingia gabonensis, Ibadan, Nigeria, 1994.
9. Ayuk ET, Duguna B, Kengue J, Mollet M, Tiki-Manga T. Zenkeng P. Uses, management and economic potential of Irvingia gabonensis in the humid lowlands of Cameroon. Forest Ecol. Manag,1999:113(1):1-9. Box G.E.P.
10. Okafor JC. Development of forest tree crops for food supplies to Nigeria. Forest Ecol. Manag,1978:17:1-11.
11. Asoegwu SN, Iroakazi GU, Agbetoye LAS, Ogunlowo AS. Some handling and frictional properties of African Breadfruit seeds as a function of Moisture content PROC National Institute Agricultural Engineers of, 2011:32·636-653.
12. Seifi MR, Alimardani R. The moisture content effect on some physical and mechanical properties of corn (Sc 704). Journal of Agricultural Science,2010:2(4):125-134.
13. Subukola OP, Onwuka VI. Effects of moisture content on some physical properties of locust bean seed (Parkiafillicoidea). Journal of Food Process Engineering,2011:34:1947-1961.
14. Amin MN, Hossain MA, Roy KC. Effects of moisture content on some physical properties of lentil seeds. Journal of Food Engineering,2004:65:83-87.
15. Desphande SO, Bal S, Ojha TP. Physical properties of Soybean. Journal of Agric. Engineering research,1993:56:89-98
16. Suthar SH, Das SK. Some physical properties of Karingda[Citrulluslanatus (thumb) Mansf] seeds. Journal of Agricultural Engineering Research,1996:65(1):15-22.
17. Nelson SO. Dimensional and density data for seeds or cereal grain and other crops. Trans-American Society of Agric. Engineers,2002:45(1):165-170.
18. Mohsenin NN. Physical properties of plant and animal materials. Gordon and Breach Science publishers, New York, 1980.
19. Garnayak DK, Pradhan RC, Naik SN, Bhatnagar N. Moisture-dependent physical properties of jatropha seed (Jatropha curcas L.). Ind. Crops Prod,2008:27:123-129.
20. Oje K, Ugbor EC. Some physical properties of oil bean seeds. Journal of Agricultural Engineering Research,1991:50:305-313.
21. Singh KK, Goswami TK. Physical properties of cumin seed. Journal of Agric EngineeringResearch,1996:64:93-98.
22. Isik E. Some physical and mechanical properties of round red Lentil grains. Applied Engineering in Agriculture,2007:23(4):503-508.
23. Tavakoli M, Tavakoli H, Rajabipour A, Ahmadi H, Gharib-zahedi SMT. Moisture-dependent physical properties of barley grains. International Journal of Agric. and Biological Engineering,2009:2(4):84-91.
24. Zareiforoush H, Komarizadeh MH, Alizadeh MR. Effect of moisture content on some physical properties of paddy grains. Journal of Applied Sciences, Engineering and Technology,2009:1(13):132-139.
25. Asoegwu SN, Ohanyere SO, Kanu OP, Iwueke CN. Physical properties of African Oil Bean Seed (Pentaclethramacrophylla). Agricultural Engineering International: the CIGR Ejournal, 2006, 7.
26. Sanchez-Mendoza J, Dominguez-Lopez A, Navarro-Galindo S, Lopez- Sandoval JA. Some physical properties of Roselle (Hibiscus sabdariffa L) seeds as a function of moisture content. Journal of food Engineering,2008:87:391-397.
27. Nimkar PM, Chattopadhyay PK. Some physical properties of green gram. Journal of Agricultural Engineering Research,2001:80(2):183-189.
28. Subukola OP, Onwuka VI. Effects of moisture content on some physical properties of locust bean seed (Parkiafillicoidea). Journal of Food Process Engineering,2011:34:1947-1961.
29. Kingly ARP, Singh DB, Manikantan MR, Jain RK. Moisture-dependent physical properties of dried pomegranate seeds (Anardana). Journal of Food Engineering,2006:75:492-496.
30. Asoiro FU, Ani AO. Determination of some physical properties of African Yam beans. The Pacific Journal of Science and Tech,2011:12(1):374-380.