Determination of Selected Physical Properties of Egusi Melon (*Citrullus colocynthis lanatus)* Seeds

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Abstract: Physical properties of seeds are determined for the purpose of developing a processing system. The aim of this research is to determine those properties that will guide the design of seed dehulling machine. In most West African countries, Egusi is grown as a food and cash crop. However, one of the most important problems is its manual dehulling, which is strenuous and time consuming. At moisture level 7.11 % dry basis, average length, thickness and width of Egusi melon seed were 13.199, 1.853 and 7.924 mm respectively. In moisture range of 7.11 to 38.70 % dry basis, studies revealed that 1000 seed mass increased from 0.0949 to 0.1299 kg and surface area from 25.394 to 27.827 mm^2. Sphericity and Porosity of seed decreased from 0.215 to 0.196 and 0.541 to 0.444 respectively, while angle of repose increased from 23.66 to 33.63°. Bulk density rose from 414.006 to 456.339 kg/m^3 while true density decreased from 901.515 to 821.668 kg/m^3. Coefficient of friction on plywood (0.3388 – 0.3598), metal (0.2767 – 0.3198), aluminium (0.2736 – 0.3172) and PVC (0.2999 – 0.3782) were recorded.

Keywords: Dimensions, porosity, density, sphericity, Porosity, coefficient of friction.

1. INTRODUCTION

Citrullus colocynthis lanatus var *lanatus* seed, one of the *cucubit* species is largely believed to have originated from western Kalahari region of Namibia and Botswana. It is grown in most African countries and used as food source, medicinal, Engineering and cosmetics [26]. It belongs with the family of *Cucurbitaceae,* which has a tremendous genetic diversity, extending to vegetative and reproductive characteristics. Researchers agree that *Citrullus lanatus* is classified into three sub-species; *lanatus, mucosospermus fursa* and *vulgaris fursa.*

Some of the species are edible and grown in most parts of the world [18]. This specie is grown and used especially as food source in most parts of West Africa. It is a vine plant which grows on the ground and covers large area when properly grown. The nature of its creepy growth on the ground control weeds, thereby improving soil fertility. It has deeply lobed and blue-gray leaves, which are alternately arranged [18; 26; 47]. The yellow-green fruit at maturity is about the size of edible watermelon, but its flesh is white and the back is often shiny. Despite its identical external look to watermelon, it has bitter taste that makes it inedible to human being.

The seeds of this melon fruit can be eaten individually as snack when roasted and used extensively for cooking purposes, either as a soup additive (thickener) or as cooking oil source. These seeds are covered with a shell which is usually removed before processing to any use. Recently, it has been proved to be a fed-stock for bio-fuel [23, 30, 45]. It is a good source of amino acids such as arginine, vitamins B_1, vitamins B_2, niacin, tryptophan and methionone, and minerals such as zinc, iron, potassium, phosphorus, sulphur, manganese, calcium, lead, chloride and magnesium [2, 17]. *Citrullus colocynthis lanatus* var. *lanatus* seed contain over 50% oil and about 30% protein and other important mineral nutrients [38]. Girgis and Said [21] concluded that the high content of unsaturated fatty and linoleic acids in Egusi melon seed suggests possible hypo-cholesteronic effect. Figure **1** shows a picture of the seeds with shell.

Figure 1: Pictorial view of “Egusi” melon seed.

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Determination of physical properties of seeds is essential for design of equipment for planting, harvesting, handling, conveying, drying, aeration, storing, and dehulling. This study is aimed at investigating some physical properties of Egusi melon seeds.

Nomenclature:			
Q	Mass of water added to seed (Kg)	M_i	Initial moisture content %)
M_f	Final moisture content (%)	W_i	Initial weight of sample (Kg)
D_a	Arithmetic mean diameter (mm)	D_g	Geometric mean diameter (mm)
L	Length of sees (mm)	T	Thickness of seed (mm)
W	Width of seed (mm)	Φ	Sphericity of seed
W_s	Weight of seed (Kg)	W_b	Weight of beaker (Kg)
W_{s+b}	Weight of seed + beaker (Kg)	V_b	Volume of beaker (/m^3)
h	Height of beaker (mm)	ρ_b	Bulk density (Kg/m^3)
ρ_t	True density (Kg/m^3)	ε	Porosity
μ	Coefficient of friction (p-plywood,	h	height of vertical stand for C of friction
	m-metal, a-aluminium, PVC- pvc	R_a	Repose angle (degrees)
D	Diameter of cone (mm)	H	Height of cone (mm)
S	Surface area (mm^2)	d	Base distance of the sliding surface

2. MATERIALS AND METHOD

Citrullus colocinthis lanatus seeds were obtained from Nigeria for the study. The sample seeds were cleaned manually to remove all excesses of foreign materials such as dust, dirt, stones, sand particles, immature or broken seeds and small chaffs from flesh of the melon fruit. Initial moisture content was determined by hot air-oven drying at 105±3^{0}C for 24 hours, following the ASAE (1994) standard S.352.3 [9, 13, 14, 24, 53]. The initial moisture content of the seed was 7.11% dry basis. Readings were repeated in ten replicates to reduce error to the acceptable level for all measurements.

Samples of desired moisture content were prepared by amount of distilled water as calculated using equation one [11, 13, 14, 24, 45, 53]. The sample seeds were stored in a tightly sealed plastic container and kept refrigerated for 3 days at 5^{0}C to allow for proper moisture distribution. This rewetting technique was used by [9, 20, 33, 40]. Before starting the experiment, only required quantity of seeds are removed and allowed to cool to room temperature for two hours.

$$Q = W_i (M_f - M_i)/(100 - M_f) \quad 1$$

Basic dimensions of the seed (length, width and thickness) were measured using digital micrometer screw gauge with accuracy of 0.001mm (Mitutoyo Digital Micrometer, Series -193) as in [5, 51]. 1000 seed mass was determined by an electronic digital balance with accuracy of 0.001g (Mitutoyo Digital Scale, Mitutoyo America Corporation**)**. To determine the average weight of 1000 seed mass, a sample size of 250 seeds were randomly selected and weighted, and the result multiplied by four [39, 42, 51].

Average bulk density of the seed was obtained using standard test weight procedure by filling a 500 ml container with seed from a height of 150 mm at a constant rate and reweighting the content. The bulk density was calculated from the mass of seed and volume of the container, with no separate manual compaction of seeds [37, 42]. Weight of seed was calculated using equation 2, Volume of the beaker was calculated from equation 3 and Bulk density was obtained from equation 4.

$$W_s = W_{s+b} - W_b \quad 2$$

$$V_b = \pi r^2 h \quad 3$$

$$\rho_b = W_s/V_b \quad 4$$

True density of the seed was determined as ratio of seed mass used to the volume of seed, using distilled water displacement method [12, 36]. This was obtained by measuring the amount of liquid displaced by immersion of seed, conforming to Archimedes principle [22, 39, 40]. The seeds were carefully placed into a

250ml beaker, containing 100ml of distilled water and the displacement of water level was recorded. Equation five uses the values of bulk and true densities to evaluate the porosity of the seed [25, 31].

$$\varepsilon = (1- \rho_b/\rho_t) \times 100 \quad 5$$

Coefficient of static friction is the ratio of force required to start sliding a given sample over a particular surface to the normal force, which is the weight of the object [7]. Static coefficient of friction of the seed, μ was evaluated using four different material surfaces; metal sheet, plywood, aluminium and plastic (PVC). Tilting platforms of 330 mm by 200 mm were used. A cylindrical shaped plastic material with both ends open and dimensions 70 mm as base and 50 mm as height was used. The material was filled with the seed and placed on the material surfaces and gently lifted, so that only the seeds are in contact with surface. The platform was lifted gently with the cylinder containing the seeds resting on it was gradually raised with a digital lifting device (Mitutoyo height measuring instrument) until the container begins to slide down the platform. Height at which the slide began was read as *h* and distance from the base of platform to the base of the screw was read as *d.* coefficient of friction μ and angle of tilt α was evaluated using equation six [8, 33, 44, 48].

$$\mu = \tan\alpha = h/d \quad 6$$

Repose angle was determined by use of an open ended circular shaped plastic material with diameters 60 mm base by 80 mm height. The container was carefully raised until it is free of the seed to obtain a cone shape by the seeds. The height of the cone was measured. The angle of repose was calculated using equation seven [19, 20, 27, 28];

$$R_a = \tan^{-1}(2H/D) \quad 7$$

Surface area of seed was determined by analogy with a sphere of same geometric mean diameter using equation 8, [3, 20, 42, 50];

$$S = \pi D_g^2 \quad 8$$

3. RESULTS AND DISCUSSION

1000 Seed Mass

Average value of M_{1000} (kg) in the moisture content range of 7.11 % to 38.70 % increased from 0.095 kg to 0.12992 kg as shown in the Table **1** and Figure **2**. Consequently, average of ten replicates produces a standard deviation of the mass from 0.005073 to 0.001064. The coefficient of correlation was 0.9987 with coefficient of determination of 0.9974. An increase of 36.9% in 1000 seed mass was recorded. Similar trend was reported on *prosopis Africana* [1], by [15] for safflower seeds and popcorn kernel [16], [20] for Jatropha seed, [40] for hemp seed and on quinoa seeds [51]. The relationship between the 1000 seed mass and moisture content is represented by equation 9.

$$M_{1000} = 0.08783 + 0.00109\ MC\ (R^2 = 0.9974) \quad 9$$

Dimensions

Variation of seed length, thickness and width with moisture content is shown in Table **1**. Figure **3** presents the variations of each parameter with moisture content. The mean dimensions of 100 seeds measured at 7.11% dry basis moisture content were: length 13.199 ± 0.464 mm, thickness 1.853 ± 0.287 mm and width 7.924 ± 0.143 mm. About 70% of the seed have a length between 13.0 to 13.57 mm; 70% have thickness

Table 1: Dimensions, 1000 Seed Mass, Surface Area, Porosity, Sphericity and Repose Angle of Seeds

Moisture Content (%)	Length (mm)	Thickness (mm)	Width (mm)	1000 seed mass (kg)	S/Area (mm^2)	Porosity	Sphericity	Repose angle (º)
7.11	13.199 ± 0.464	1.853 ± 0.287	7.924 ± 0.143	0.095 ± 0.005	25.394	0.5408	0.2154	23.661
14.65	13.633 ± 0.193	2.019 ± 0.093	8.032 ± 0.126	0.105 ± 0.001	25.913	0.5213	0.2107	26.221
28.07	13.953 ± 0.275	2.266 ± 0.107	8.194 ± 0.484	0.118 ± 0.002	26.442	0.4850	0.2079	29.701
38.70	15.211 ± 1.036	2.557 ± 0.272	8.589 ± 0.530	0.13 ± 0.001	27.827	0.4446	0.1956	33.630

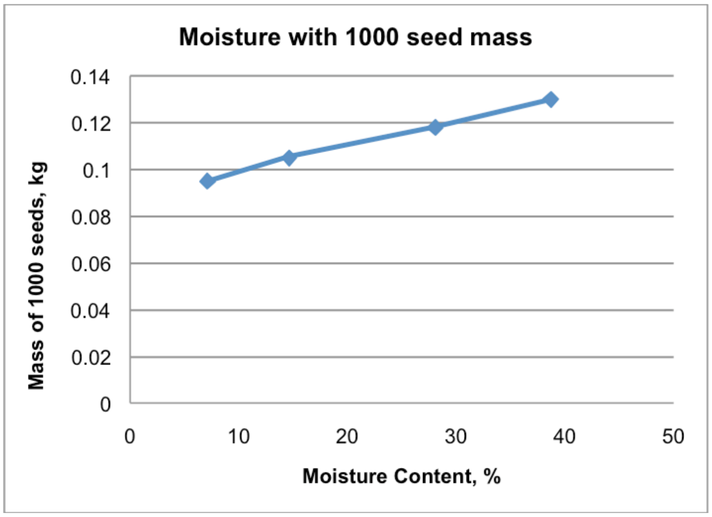

Figure 2: Moisture content variation with 1000 seed mass.

between 1.62 to 1.99 mm and about 80% have between 7.75 to 7.99 mm as width. Consequently, the absorption of moisture increases the size of the seed [11, 18, 33, 44]. Length of seed increased from 13.2 mm to 15.3 mm, thickness from 1.85 mm to 2.56 mm while width of the seed rose from 7.92 mm to 8. 59 mm within the moisture content range of 7.11 % to 38.70 %. Values of length, thickness and width were related to the moisture content as in equations 10, 11 and 12;

$$L = 12.7055 + 0.05844\ MC\ (R^2 = 0.8998) \qquad 10$$

$$T = 1.6924 + 0.02176\ MC\ (R^2 = 0.9929) \qquad 11$$

$$W = 7.7431 + 0.01996\ MC\ (R^2 = 0.9257) \qquad 12$$

Surface Area

Surface area of the seed has increased with the increase in moisture content. This is expected since the surface area is a function of geometric diameter (Table **1** and Figure **4**). It increased from 25.39 to 27.83 mm^2. Similar report was presented by [13] on fenugreek seeds; [15] on safflower; [36] on calabash nutmeg seeds. Surface area and moisture content were related by equation 13;

$$S_a = 24.7978 + 0.07212\ MC\ (R^2 = 0.9355) \qquad 13$$

Porosity

This is a property that depends on the densities (bulk and true) and differs with seed. It was observed to decrease with increase in the moisture content as shown in Figure **5**. It is the "empty" space in the seed. It is useful especially in seed storage and processing, as it guides in knowing the amount of seed that goes into the planter tube or dehuller. The experiment shows that it decreases from 0.541 to 0.445 with increase in

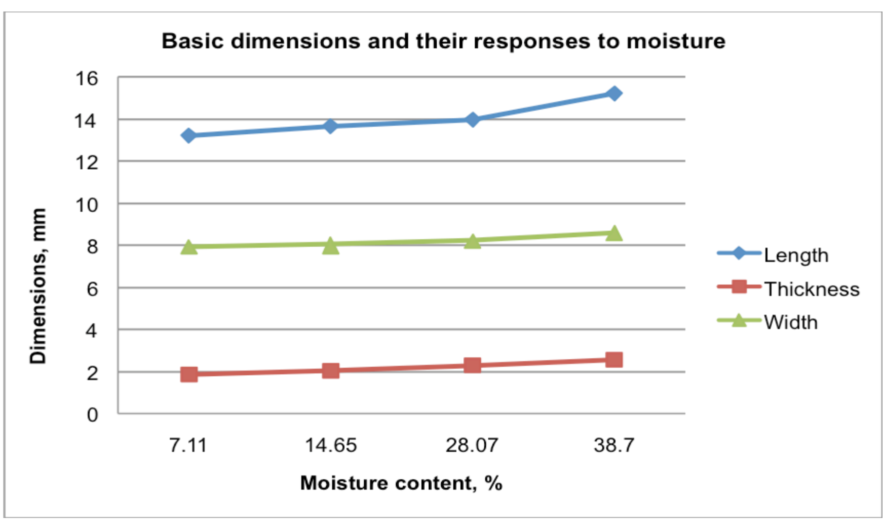

Figure 3: Moisture variation with Length, Thickness and Width of seed.

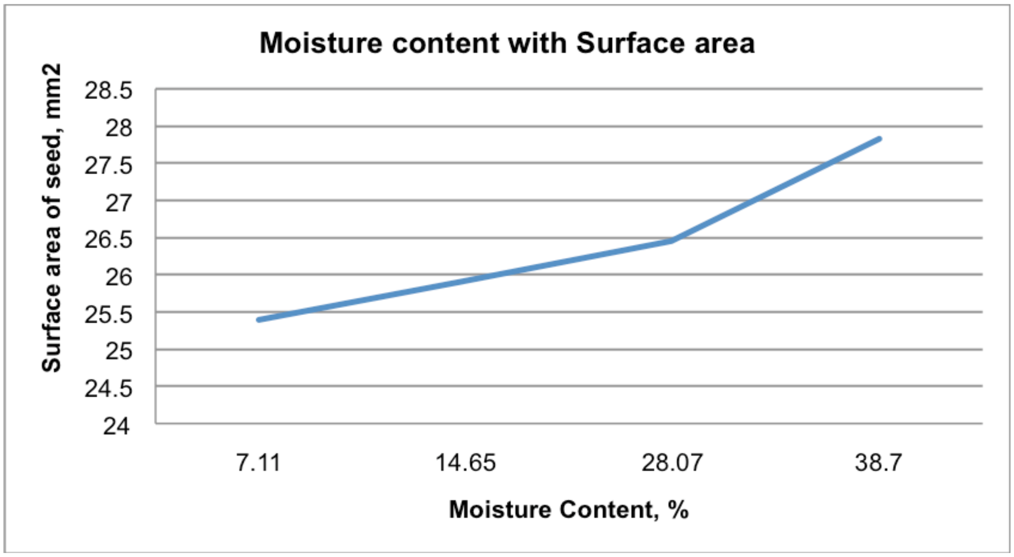

Figure 4: Surface area variation with moisture.

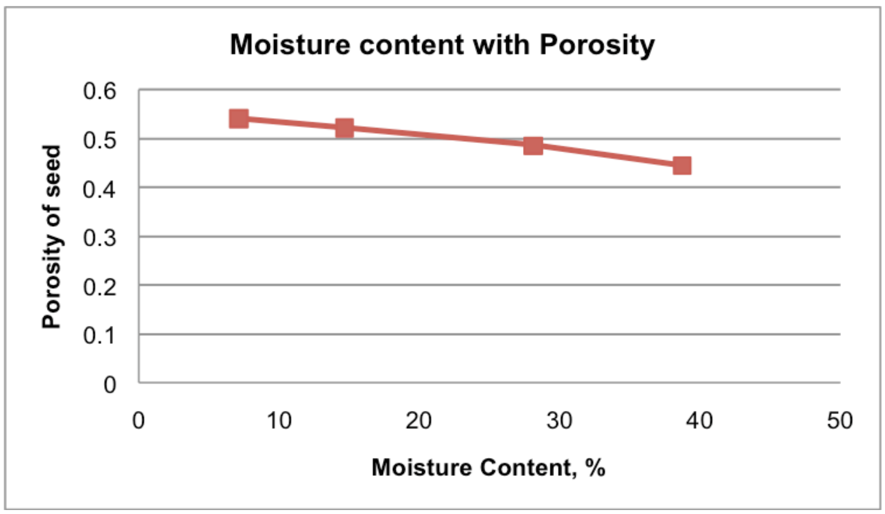

Figure 5: Variation of porosity with moisture content.

moisture content from 7.11 to 38.70%. The relationship to moisture content is represented by equation 14;

$$P = 0.5645 – 0.003\ MC\ (R^2 = 0.9922) \qquad 14$$

Similar trend was reported by [10] on soybeans; [11] on sugar beet; [40] on hemp seed, [48] on karingda seeds [52] on neem nut. However, [20] on jatropha, reported porosity increase. Table **1** explains further.

Sphericity

Sphericity of the seed decreases with increase in moisture content. This is similar to findings of [12, 34, 41] on gram and oil bean and rapeseed respectively. Table **1** and Figure **6** show the relationship of moisture content with sphericity. It decreases from 0.2154 to 0.1956 with increase of moisture content from 7.11 to 38.70%. The sphericity can be described by equation 15.

$$S = 0.2200 + 0.00057\ MC\ (R^2 = 0.8973) \qquad 15$$

True and Bulk Densities

True density decreased with the increase in moisture content as shown in Table **2**, as was similarly reported by [12, 22, 36, 39, 40]. The volume of the displaced fluid increased with moisture, while the mass of seed was constant. At 7.11% the true density was 901.515 kg/m^3, and decreases to 821.668 kg/m^3 at 38.70% moisture level. The decreasing relationship is almost linear. Figure **7** shows the relationship with the moisture. The densities are related to moisture content by equations 16 and 17;

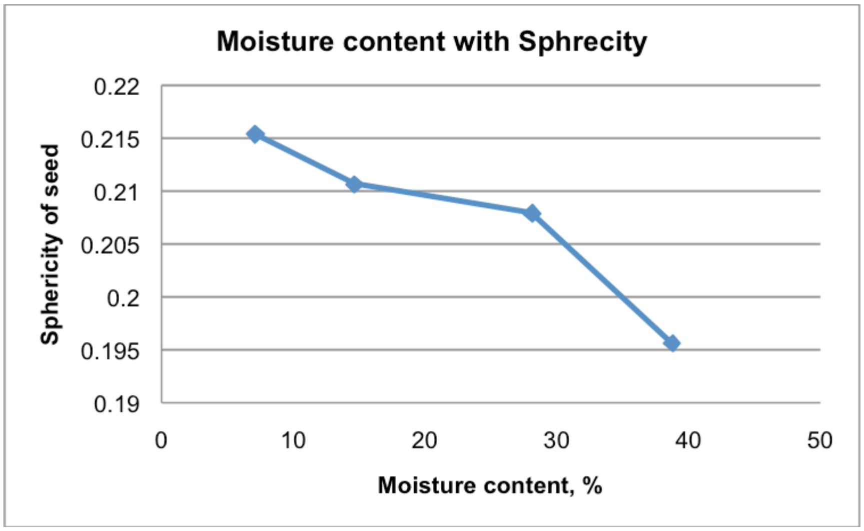

Figure 6: Variation of sphericity with moisture.

Table 2: Moisture Content and Coefficient of Friction on Different Surfaces

Moisture Content (%)	Bulk Density (kg/m3)	True Density (kg/m3)	Coefficient of Friction Plywood	Coefficient of Friction Metal	Coefficient of Friction Alum.	Coefficient of Friction PVC
7.11	414.006 ± 2.424	901.515 ± 49.091	0.3388	0.2767	0.2736	0.2999
14.65	424.076 ±4.921	885.838 ± 40.253	0.3428	0.2900	0.2887	0.3189
28.07	438.599 ± 0.819	851.587 ± 22.505	0.3483	0.2964	0.3010	0.3408
38.70	456.339 ± 6.092	821.668 ± 37.131	0.3598	0.3198	0.3172	0.3782

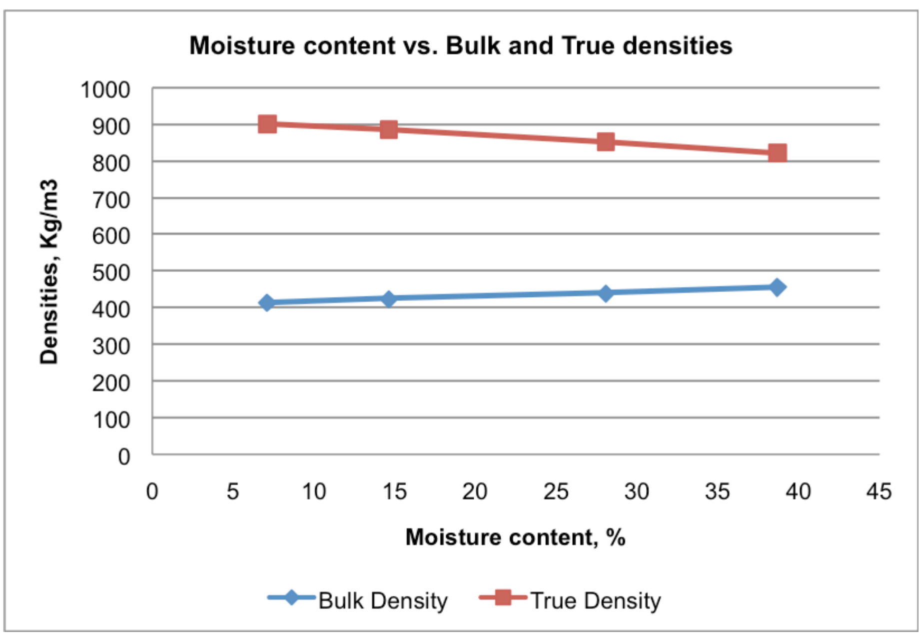

Figure 7: Moisture content vs. True density and Bulk density.

$$T_d = 921.3631 - 2.53976\ MC\ (R^2 = 0.9973) \qquad 16$$

Bulk density increased with the moisture content from 414.006 kg/m^3 at 7.11% to 456.339 kg/m^3 at 38.70% moisture level. The pattern was similarly reported by [6, 29, 37, 42] on terebinth, dried pomegranate, African star apple and tung seed respectively. Volume of the container was the same

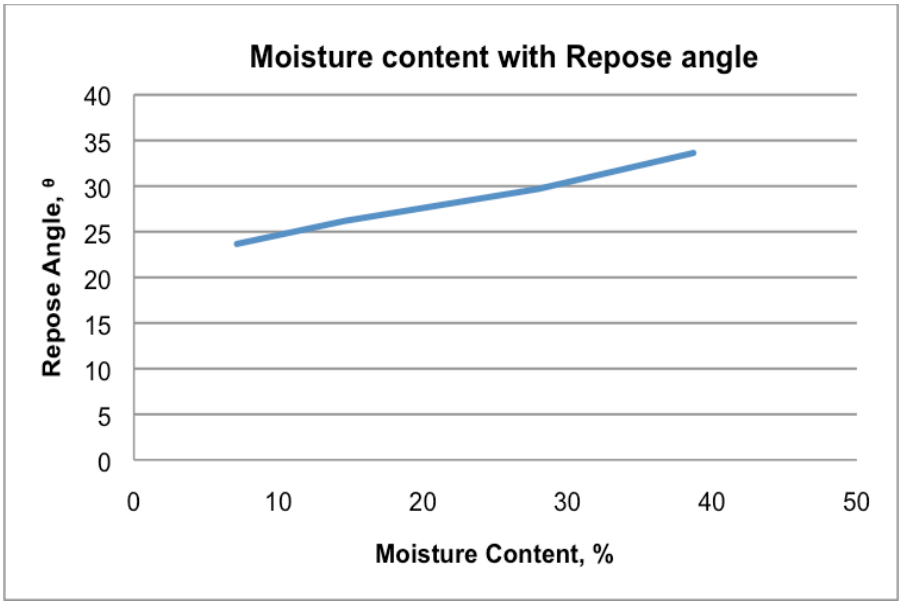

Figure 8: Moisture content and Repose angle.

and mass of the seed linearly increases with the additional moisture.

$\rho_d = 404.3628 + 1.30542\ MC\ (R^2 = 0\ .9917)$ 17

Repose Angle

The repose angle increases with the moisture content from 23.66 to 33.63^0 as moisture increases from 7.11 to 38.70%. Friction increases on the surface of the seeds, thereby making the seeds less able to flow on one another. Similar trend was reported by [19, 20, 27, 28]. Responses of the seed in making "cone" with increasing moisture are shown in Figure **8**. Equation 18 relates the two variables;

$R_a = 21.4970 + 0.30752\ MC\ (R^2 = 0.9949)$ 18

Coefficient of Friction

Four different surfaces were used in the experiment; plywood, plastic (PVC), metallic and aluminium foil surfaces. The coefficients of friction of seeds were determined under different values of moisture contents. In each case, ten replicates of experiments were conducted. Figure **9** depicts the trends and correlation

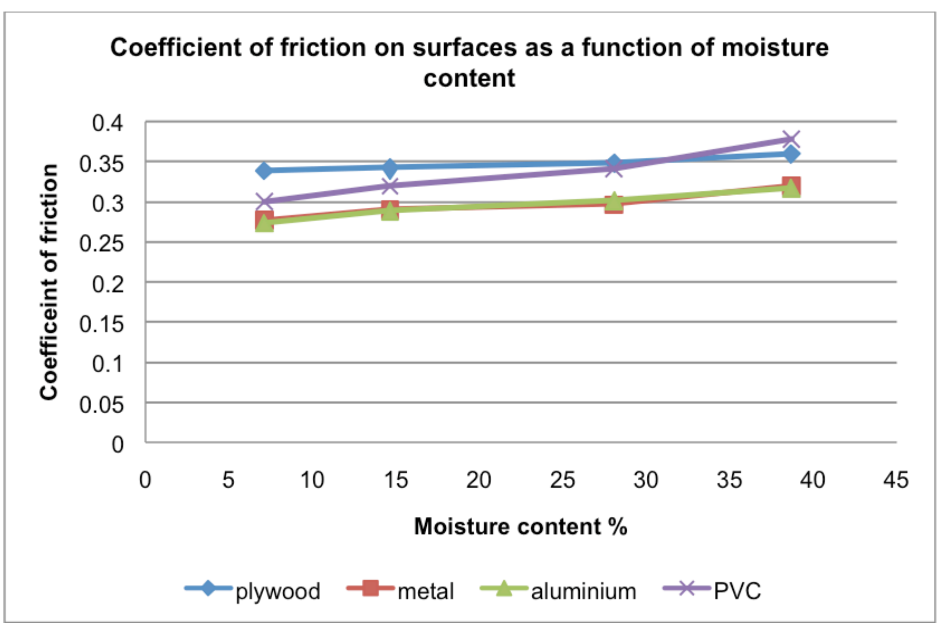

Figure 9: Variation of moisture and frictions on different surfaces.

values are shown in Table **2**. On all the surfaces experimented on, the value of coefficient of friction increased with increasing moisture value. It was from 0.3388 to 0.3598, 0.2767 to 0.3198, 0.2736 to 0.3172 and 0.2999 to 0.3782 for plywood, metal, aluminium and PVC surfaces respectively from 7.11% to 38.70%. The coefficient of friction of seeds is required in design of silos and hopper for processing systems.

$$Cf_{plywood} = 0.3334 + 0.00063\ MC\ (R^2 = 0.9973) \quad 19$$

$$Cf_{metal} = 0.2683 + 0.0012\ MC\ (R^2 = 0.9973) \quad 20$$

$$Cf_{aluminium} = 0.2662 + 0.0013\ MC\ (R^2 = 0.9973) \quad 21$$

$$Cf_{PVC} = 0.2821 + 0.00236\ MC\ (R^2 = 0.9973) \quad 22$$

Similar trends were reported by [4] on lentil seeds; [29] on pomegranate; [45] on niger seeds [49] on pumpkin seeds.

4. CONCLUSION

The following conclusions were drawn from the investigation on some physical properties of Egusi melon seed for the moisture content range of 7.11 to 38.70%;

1. Bulk density of the seed increased from 414.006 kg/m^3 to 456.339 kg/m^3, while true density falls from 901.515 kg/m^3 to 821.668 kg/m^3.

2. Angle of repose rose from 23.661^0 to 33.630^0 within the range of moisture and thousand seed mass also increased from 0.09491 Kg to 0.1299 Kg, similar to surface area from 25.39 mm^2 to 27.83 mm^2

3. Both sphericity and porosity reduces within the range from 0.215 to 0.196 and 0.541 to 0.444 respectively, and Coefficient of friction on the four tested surfaces also increased; plywood (0.3388 – 0.3598), metal (0.2767 – 0.3198), aluminium (0.2736 – 0.3172) and PVC (0.2999 – 0.3782).

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