Variation of Physical Properties of Egusi Melon (Citrullus Colocynthis Lanatus Var. Lanatus) Seeds and Kernel with Moisture

Bande, Y. M.*(1), Adam, N. M.*Azmi, Y.** and Jamarei,O.**
*Department of Mechanical and Manufacturing Engineering
**Department of Biological and Agricultural Engineering
Faculty of Engineering, University Putra Malaysia
43400 Serdang
Selangor Darul Ehsan
Malaysia
(1) Tel: +60-3-89466345; Fax: +60-3-86567122.
Email: ymbande@yahoo.com

***Abstract*-- Determination of physical properties of seed and kernel is aimed at developing mechanical devices for processing, storage or transportation. Egusi melon is grown only for its kernel more as a cash crop than food crop. The major bottle-neck is its mechanical dehulling. The development of this system will help small and middle scale farmers in farming and utilizing the cash crop. 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 while the kernel was11.2, 1.378 and 6.424 mm respectively, measured with digital caliper. In moisture range of 7.11 to 38.70 % dry basis, studies revealed that 1000 seed mass increased from 94.9 to 129.9 g and surface area from 25.4 to 27.8 mm^2, kernel mass increased from 87 to 108 g and surface area from 22.37 to 24.72 mm^2. Geometric and arithmetic mean diameters rose from 2.83 to 2.98 and 7.66 to 8.79 respectively for seed and 2.67 to 2.81 and 6.33 to 7.35 respectively for the kernel. Sphericity and Porosity of seed decreased from 0.215 to 0.196 and 0.541 to 0.444 in the seed and 0.24 to 0.22 and 0.54 to 0.46 respectively for the kernel. Angle of repose increased in both, while true density decreased. Coefficient of friction on plywood, metal sheet, aluminium and plastic material (PVC) all increased in both seed and kernel with moisture increase.**

***Index Term*-- Repose angle, Porosity, Sphericity, Surface area, Arithmetic mean diameter, Geometric mean diameter**

I. INTRODUCTION

One of the important food and cash crops that is grown in most African countries is Egusi *(Citrullus colocynthis lanatus* var *lanatus*)and used as food source, in medicine, engineering and cosmetics [28]. It belongs with the family of *Cucurbitaceae,* with excellent genetic diversity, vegetative and reproductive characteristics. *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 [20]. Egusi is grown and utilized as food source in most parts of Africa. It is in nature, a creepy growing plant which covers large area when properly grown, and as such control weeds, thereby improving soil fertility. Its leaves are deeply lobed and blue-gray, and are alternately arranged [20, 28]. The yellow-green fruit at maturity, which is identified by the drying of its leaves, is about the size of edible watermelon, but its flesh is white and the back is often shiny.

Kernels of this seeds can be eaten individually as snack when roasted and used extensively for cooking purposes, either as a soup additive or as cooking oil source. Recently, it has been proved to be a fed-stock for bio-fuel [25, 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, 19]. The oil content is over 50% and about 30% protein and other important mineral nutrients [37]. High content of unsaturated fatty and linoleic acids in Egusi melon seed suggests possible hypo-cholesteronic effect [23].

Determination of physical properties of seeds is essential for design of equipment and other facilities for planting, harvesting, handling, and conveying, drying, aeration, storing, and dehulling [8]. This study is aimed at investigating physical properties of egusi melon seeds and kernels, with a view to develop a mechanical dehulling system. These are necessary so that the component requirement for a successful dehulling without grinding the kernel, which is soft in nature, can be developed.

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
SE	Standard Error
R^2	Coefficient of determination

II. MATERIALS AND METHODS

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. Seeds were manually dehulled to obtain the kernel. Initial moisture contents of both were determined by hot air-oven drying at 105±3^{0}C for 24 hours, following the ASAE (1994) standard S.352.3 [11, 15, 16, 26, 51]. The initial moisture content of the seed and kernel were 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 adding amount of distilled water as calculated using equation one [13, 15, 16, 26, 44, 51]. The sample seeds and kernel were stored in a tightly sealed plastic container and kept refrigerated for 3 days at 5^{0}C to allow for proper moisture distribution. Before starting the experiments, only required quantity of seeds or kernels were removed and allowed to cool to room temperature. This rewetting technique was used by [11, 22, 38, 39].

$$Q = W_i (M_f – M_i)/(100 – M_f) \qquad 1$$

The properties of the seeds and kernels were evaluated at moisture levels of 7.11 %, 14.65 %, 28.07 % and 38.70 % dry basis, with ten replications.

As in [6, 49], length, width and thickness of the seeds and kernels were measured using digital micrometer screw gauge with accuracy of 0.001mm (Mitutoyo Digital outside Micrometer, Series -193). 1000 seed mass and 1000 kernel mass were determined by an electronic digital balance with accuracy of 0.001g (Mitutoyo Digital Scale, Mitutoyo America Corporation**)** as in [38, 41, 49].

Arithmetic and geometric mean diameters D_a, D_g and sphericity of seed and kernel were evaluated using basic dimensions (length, width and thickness). These were computed using equations two, three and four [9, 32, 42] respectively;

$$D_a = (L+W+T)/3 \qquad 2$$

$$D_g = (LWT)^{1/3} \qquad 3$$

$$\Phi = (LWT)^{1/3}/L \qquad 4$$

Average bulk densities were obtained using standard test weight procedure. This was conducted by filling a 500 ml container with seed or kernel from a height of 150 mm at a constant rate and reweighting the content. Bulk densities were calculated from the mass of seed (or kernel) and volume of the container, with no compaction [36, 41]. Weight (eq. 5), Volume of the beaker (eq. 6) and Bulk density (eq. 7)

$$W_s = W_{s+b} - W_b \qquad 5$$

$$V_b = \pi r^2 h \qquad 6$$

$$\rho_b = W_s/V_b \qquad 7$$

True densities were determined as ratio of seed mass to volume of seeds or kernels, using distilled water displacement method [14, 35]. This was obtained by measuring the amount of liquid displaced by immersion of seed [24, 38, 39]. Porosity of the seed and kernels were obtained using the values of bulk and true densities, as in equation eight [27, 32].

$$\varepsilon = (1- \rho_b/\rho_t) \times 100 \qquad 8$$

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 [9]. Static coefficient of friction of the seed and kernel, μ was evaluated using four different material surfaces; metal sheet, plywood, aluminium and plastic (PVC). A cylindrical shaped plastic material with open ends was used. The plastic material was placed on the surface, filled to brim and gently lifted, so that only seeds or kernels were in contact with surface. The platform was lifted gently with a digital lift (Mitutoyo Vertical 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 nine [10, 38, 43, 46].

$$\mu = \tan\alpha = h/d \qquad 9$$

Using an open ended circular shaped plastic material, repose angle was determined. The container was carefully raised until it is free of the seed to obtain a cone shape by the seeds or the kernel. The height of the cone was measured. The angle of repose was calculated using equation ten [21, 22, 29, 30];

$$R_a = \tan^{-1} (2H/D) \qquad 10$$

Surface area of seed and kernel was determined from the geometric mean diameter using equation 11, [3, 8, 22, 41, 48];

$$S = \pi D_g^2 \qquad 11$$

III. RESULTS AND DISCUSSIONS

1000 SEED MASS

Average value of M_{1000} (g) in the moisture content range of 7.11 % to 38.70 % increased from 94.91 g to 129.92 g as kernel's increased from 87 g to 108 g as shown in the Table one and Figure one. Consequently, average of ten replicates produces a standard deviation of the mass from 5.073 to 1.064g for seed and from 3 to 8g for kernel. The coefficient of determination of 99.74% for seed and for kernel, coefficient determination of 89.92% was obtained. Within the moisture range, an increase of 36.9% in 1000 seed mass was recorded. Similar trend was reported by [18] for popcorn kernel, on *prosopis Africana*, [1] and on quinoa seeds, [49]. [39]for hemp seed, [22] for Jatropha seed and [17] for safflower seeds. The relationship between the 1000 seed mass and moisture content is therefore represented by the equation 12 (a) and 12 (b) for kernel.

M_{1000} = 0.08783+ 0.00109 MC (R^2=0.9974, SE=0.00095) 12(a)

M_{1000} = 0.082+0.0006 MC (R^2=0.8992, SE=0.0035) 12 (b)

Dimensions

Variation of length, thickness and width in seeds and kernels with moisture content is shown in Table 1. Figure 2 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. However, in kernel, length 11.2 mm, thickness 1.378 mm and width 6.424 mm were recorded. About 70% of the seed have a length between 13.0 to 13.57 mm; 70% have thickness between 1.62 to 1.99 mm and about 80% have between 7.75 to 7.99 mm as width. A close record for kernel was recorded as About 71% of the kernels have a length between 11.0 to 11.23 mm; 73% have thickness between 1.29 to 1.39 mm and about 86% have between 6.40 to 6.45 mm as width. Consequently, the absorption of moisture increases the size of the kernel and seed [13, 20, 38, 43]. The values of length, thickness and width were related to the moisture content as given in the following equations 13 (a), 14 (a) and 15 (a); and for kernel, the relationship with moisture content is defined by equations 13(b), 14(b) and 15(b).

L = 12.7055 + 0.05844 MC (R^2 = 0.8998) 13 (a)

T = 1.6924 + 0.02176 MC (R^2 = 0. 9929) 14 (a)

W = 7.7431 + 0.01996 MC (R^2 = 0.9257) 15 (a)

L = 10.79 + 0.0454 MC (R^2 = 0.9431) 13 (b)

T = 1.25 + 0.0295 MC (R^2 = 0. 9570) 14 (b)

W = 6.53 + 0.0015 MC (R^2 = 0.0014, SE = 0.718) 15 (b)

Arithmetic and Geometric diameters

The arithmetic and geometric diameters were found to have increased with moisture content as similarly reported by [9] on garlic; [14] on gram seeds; [41] on tung seeds; [6] on guna seeds, and were tabulated in Table 1 and Figure 3. These parameters were therefore directly related to basic dimensions and as such, increase in length, thickness and width of the seeds and kernels produces corresponding increase in the diameters. Arithmetic and geometric mean diameters increased from 7.66 mm to 8.79 mm and 2.84 mm to 2.98 mm respectively in seed and similarly from 6.334 mm to 7.354 mm and 2.668 mm to 2.805 mm in kernel as moisture content rose from 7.11 % to 38.70 %.

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 mm^2 to 27.83 mm^2 in seed and 22.37 mm^2 to 24.72 mm^2in kernels. Similar report was presented by [15] on fenugreek seeds; [17] on safflower; [35] on sorrels seeds.

Surface area and moisture content were related by equation 16(a) for seed and 16(b) for kernel;

S_a = 24.7978 + 0.07212 MC (R^2 = 0.9355) 16(a)

S_a = 22.054 + 0.0584 MC(R^2 = 0.6712) 16(b)

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 a value of the "empty" space in the seed or kernel. 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 showed that it decreases from 0.541 to 0.445 in seed and 0.539 to 0.464 in kernel, with increase in moisture content from 7.11% to 38.70%. Porosity relationship to moisture content is represented by equation 17(a) and for the kernel, equation 17(b);

P = 0.5645 – 0.003 MC (R^2 = 0.9922, SE = 0.0046) 17(a)

P = 0.5553 – 0.0024 MC (R^2 = 0.9997, SE = 0.00122) 17(b)

Similar trend was reported by [50] on neem nut; [13] on sugar beet; [12] on soybeans; [39] on hemp seed, [46] on karingda seeds. However, [22] on jatropha, reported porosity increase. Table 1 explains the correlation relationship with the moisture.

Sphericity

Sphericity of both seed and kernel decreased with increase in moisture content. The value of length which is the denominator of the sphericity equation increased as moisture increases. This is similar to findings of [14, 34, 40] on rapeseed, gram and oil bean respectively. Table 5 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% in seed and a decrease was recorded for kernel from 0.2383 to 0.2210. The sphericity can be described by equation 18(a) in seed and 18(b) in kernel.

S = 0.2200 - 0.00057 MC(R^2 = 0.8973, SE = 0.0033) 18(a)

S = 0.2445 - 0.0006 MC (R^2 = 0.9450, SE = 0.00245) 18(b)

True and Bulk Densities

True density decreased with the increase in moisture content as shown in Table 2, as was similarly reported by [14, 24, 35, 38, 39]. The volume of the displaced fluid increased with moisture, while the mass of seed was constant. This is similar to the kernel. At 7.11% the true density of seed was 901.515 kg/m^3, and decreases to 821.668 kg/m^3 at 38.70% moisture level, and was 854.52 kg/m^3, and decreases to 813.67 kg/m^3. The decreasing relationship is almost linear. Figure 7 shows the relationship with the moisture. True density is related to moisture content by equation 19(a) for seed and 19(b) for kernel;

$$T_d = 921.3631 - 2.53976\,MC \quad (R^2 = 0.9973) \qquad 19(a)$$

$$T_d = 859.873 - 1.0604\,MC \quad (R^2 = 0.7710) \qquad 19(b)$$

Bulk density of both seed and kernel 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 and from 394.00 kg/ to 436.34 kg/m^3 respectively. This is depicted by Table 2. This pattern was similarly reported by [36, 41]; [7] on terebinth; [31] on dried pomegranate. The volume of the container was the same and the mass of the seed and kernel linearly increases with the additional moisture. It is similarly described by the equation 20(a) for seed and 20(b) for kernel;

$$\rho_d = 404.3628 + 1.30542\,MC \quad (R^2 = 0\,.9917) \qquad 20(a)$$

$$B_d = 383.451 + 1.441\,MC \quad (R^2 = 0\,.9653) \qquad 20(b)$$

Repose Angle

The repose angle increases with the moisture content from 23.66^0 to 33.63^0 and from 27.66^0 to 39.43^0 in seed and kernel respectively, as moisture increases from 7.11% to 38.70%. Friction increases on the surface of both kernel and seeds with moisture, thereby making the seeds less able to flow on one1. another. Similar trend was reported by [21, 22, 29, 30]. Responses of the seed in making "cone" with increasing moisture are shown in Figure10. Equation 21(a) relates the two variables in seed and 21(b) in kernel;

$$R_a = 21.4970 + 0.30752\,MC \quad (R^2 = 0.9949) \qquad 21(a)$$

$$R_a = 25.681 + 0.3387\,MC \quad (R^2 = 0.9455) \qquad 21(b)$$

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 and kernels were determined under different values of moisture contents. In each case, ten replicates of experiments were conducted. Figure 9 depicts the trends and correlation values are shown in Table 3. 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 with seed and 0.4588 to 0.5598, 0.5369 to 0.6198, 0.4872 to 0.5484 and 0.3108 to 0.3729 for kernel on plywood, metal, aluminium and PVC surfaces respectively from 7.11% to 38.70%. The coefficient of friction of seeds is required in design of processing systems and in silos design. Coefficients of friction on different surfaces were related to the moisture content equations 22(a), 23(a), 24(a) and 25(a) for seeds and 22(b), 23(b), 24(b) and 25(b) for kernel respectively.

$$Cf_{plywood} = 0.3334 + 0.00063\,MC \quad (R^2 = 0.9973,\ SE = 0.0025) \qquad 22(a)$$

$$Cf_{metal} = 0.2683 + 0.0012\,MC \quad (R^2 = 0.9973,\ SE = 0.0059) \qquad 23(a)$$

$$Cf_{aluminium} = 0.2662 + 0.0013\,MC \quad (R^2 = 0.9973,\ SE = 0.00304) \qquad 24(a)$$

$$Cf_{PVC} = 0.2821 + 0.00236\,MC \quad (R^2 = 0.9973,\ SE = 0.00654) \qquad 25(a)$$

$$Cf_{plywood} = 0.4408 + 0.0003\,MC \quad (R^2 = 0.1295,\ SE = 0.00778) \qquad 22(b)$$

$$Cf_{metal} = 0.5253 + 0.0024MC \quad (R^2 = 0.073,\ SE = 0.0085) \qquad 23(b)$$

$$Cf_{aluminium} = 0.4734 + 0.0019\,MC \quad (R^2 = 0.8963,\ SE = 0.0027) \qquad 24(b)$$

$$Cf_{PVC} = 0.3050 + 0.0017\,MC \quad (R^2 = 0.2251,\ SE = 0.0099) \qquad 25(b)$$

Similar trends were reported by [31] on pomegranate; [4] on lentil seeds; [47] on pumpkin seeds; [44] on niger seeds.

The following summary was drawn from the regression anaysis on physical properties of Egusi melon seed and kernel for the moisture content range of 7.11 % to 38.70%;

1. Bulk density of the seed and kernel, while true density falls in each case.
2. Angle of repose rose from within the range of moisture and so do the thousand seed and kernel. Similarly, surface area.
3. Both sphericity and porosity reduces. Coefficient of friction on the four tested surfaces also increased.

IV. CONCLUSIONS

The responses of the physical properties of both the seeds and kernels of the Egusi melon with the moisture content as obtained from this paper can guide the design of the mechanical dehulling machine. Thus, the design of hopper can be made from information on the repose angle, the orger from information on surface area, sphericity, and basic dimensions, the cleaning chamber will utilize the readings of the kernel. The research therefore gives all information necessary for the design of a mechanical device for the dehulling and cleaning of the Egusi *(Citrullus colocinthis lanatus* var. *lanatus*).

V. SCOPE AND LIMITATIONS

The research is limited only to the determination of the physical properties of the seeds and kernels. The purpose was to guide the design of the mechanical processing machine. It was subjected to different moisture values so as to determine the response of the seeds and kernel in relation to the properties. This is important as it will guide the machine designer to obtain the required output of kernels after processing.

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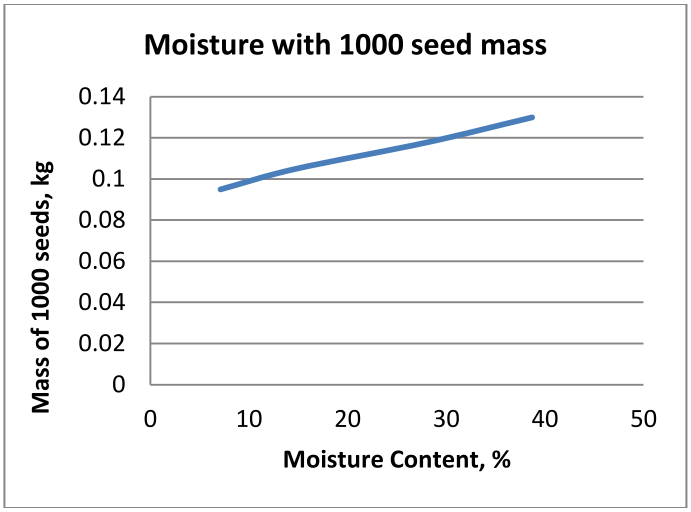
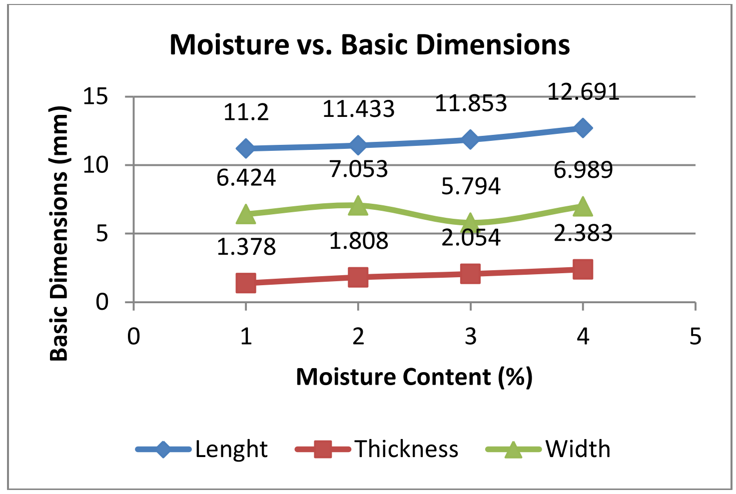
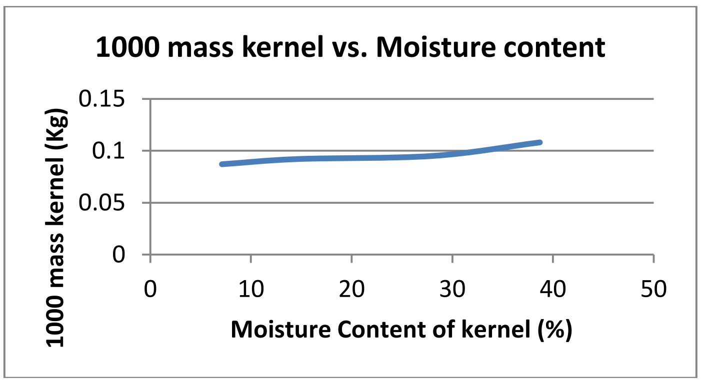


1(a)



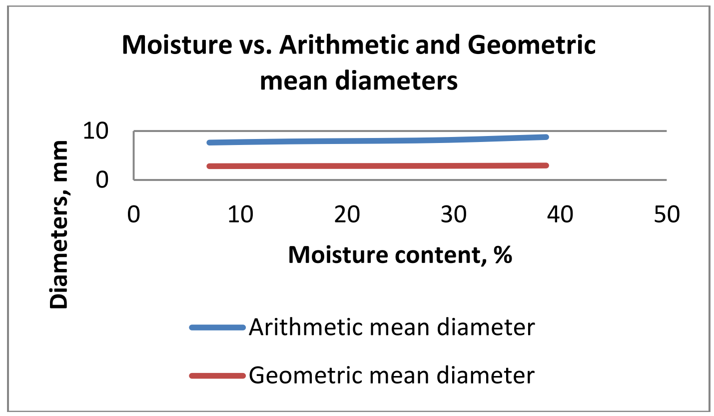
2(b)

Fig. 2. Moisture variation with Length, Thickness and Width of; (a) seed; (b) kernel



1(b)

Fig. 1. (a): 1000 seed mass; (b) 1000 kernel mass



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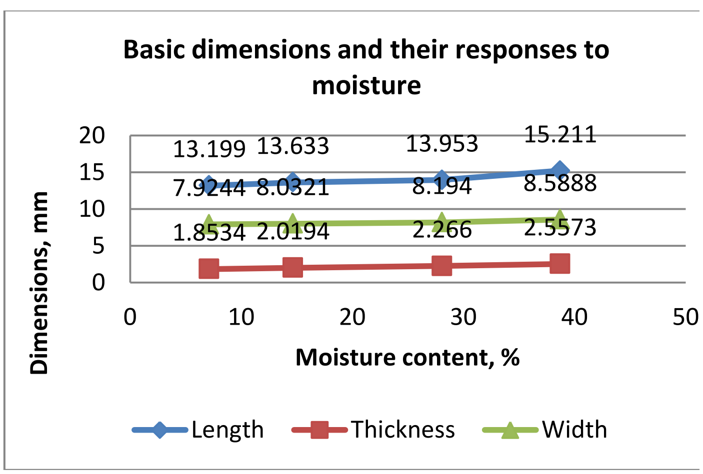

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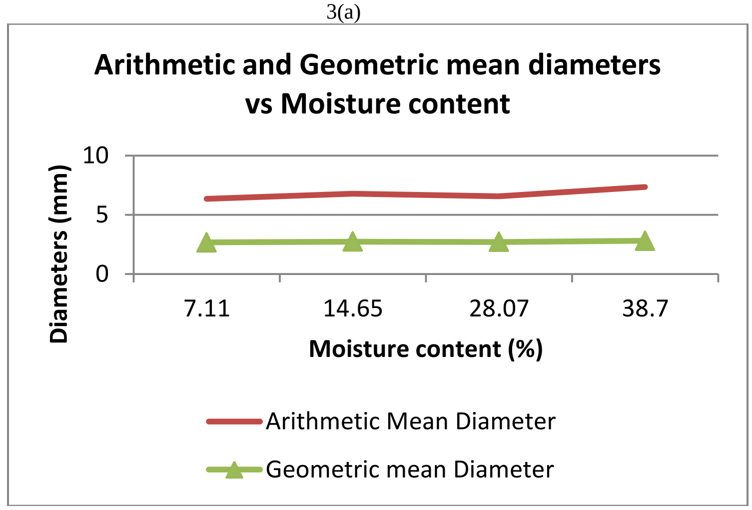
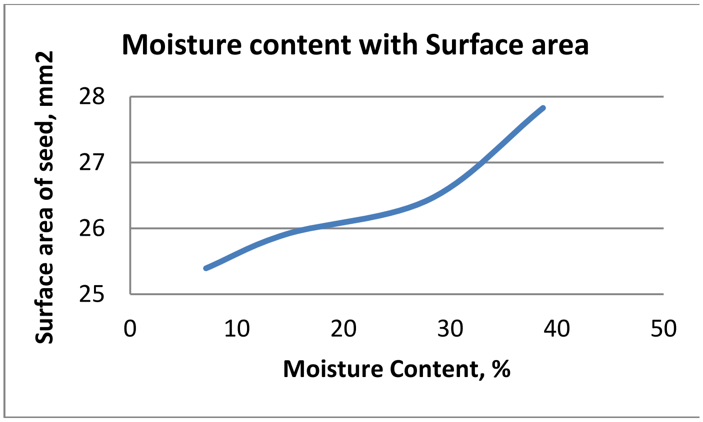
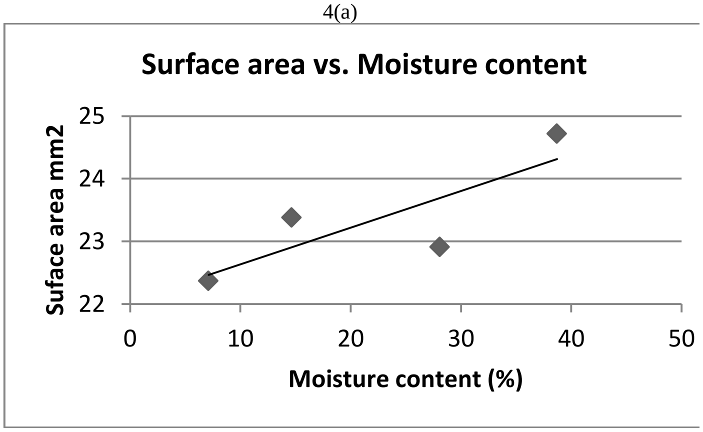


3(b)

Fig. 3. Moisture vs. Arithmetic and Geometric mean diameters: (a) seed, (b) kernel

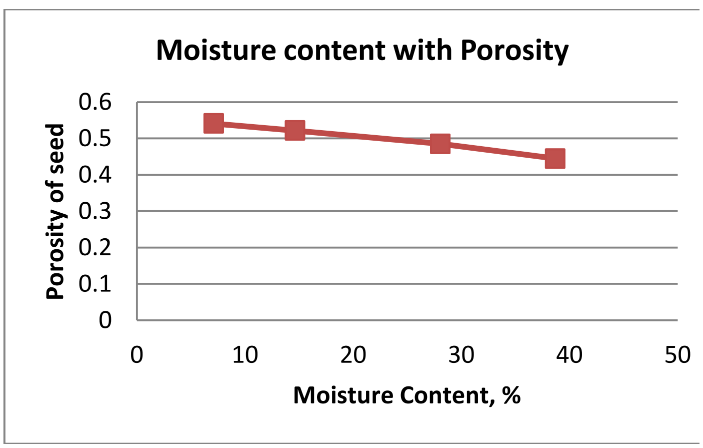


4(a)

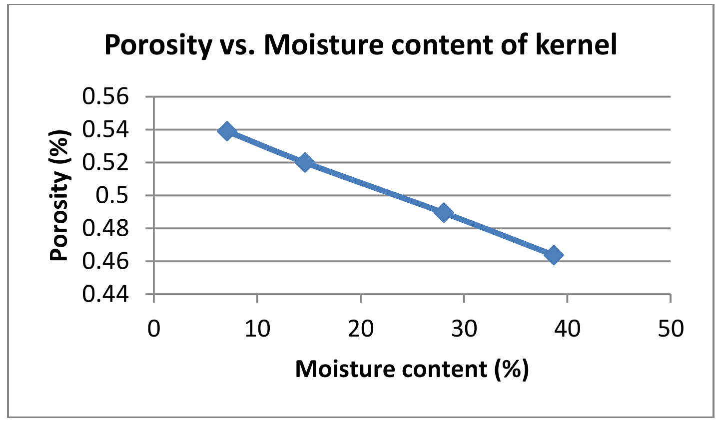


4(b)

Fig. 4. Surface area variation with moisture (a) seed and (b) Kernel

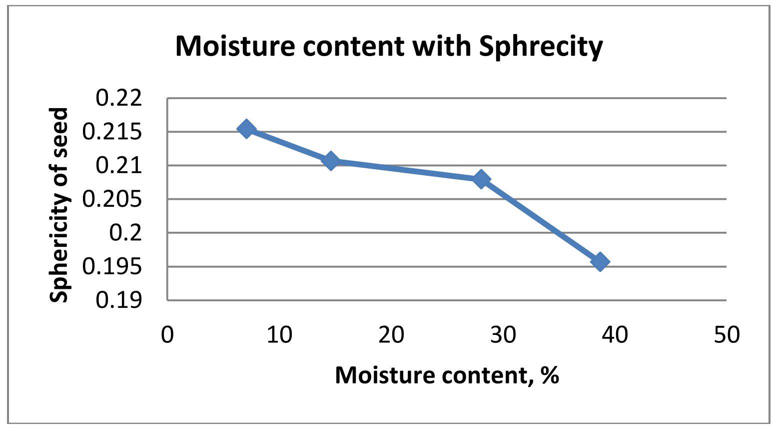


5(a)

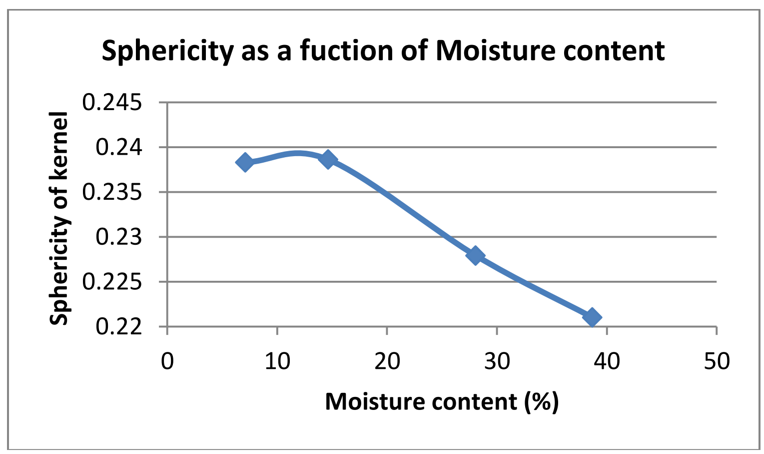


5(b)

Fig. 5. Variation of porosity with moisture content: (a) seed, (b) kernel

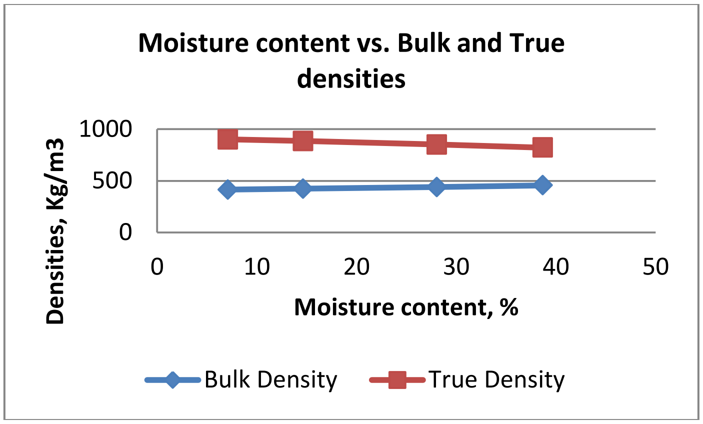


6(a)

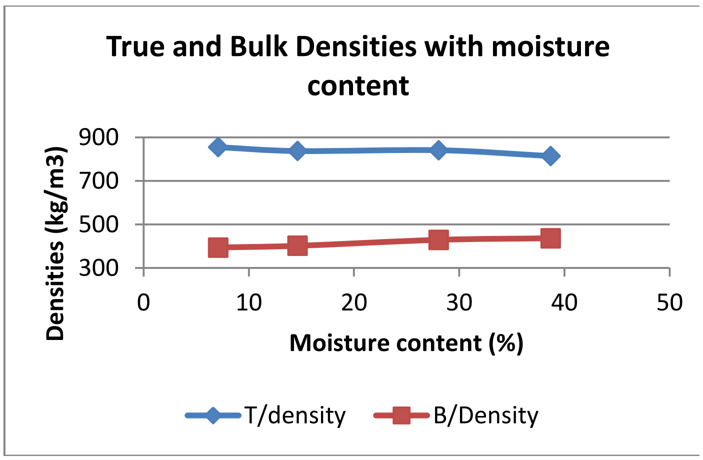


6(b)

Fig. 6. Variation of sphericity with moisture; (a) Seed, (b) kernel

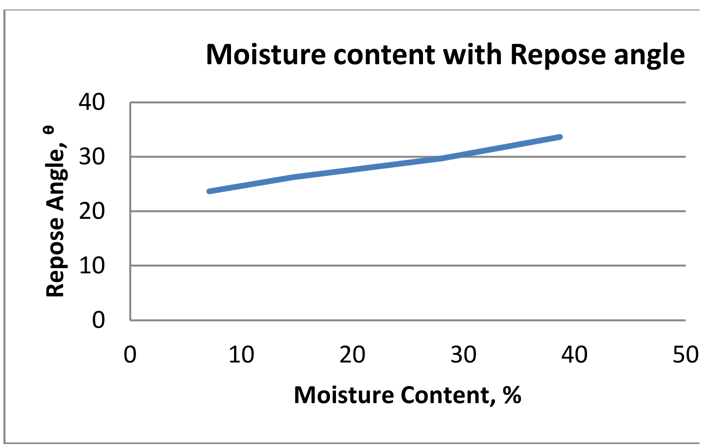


7(a)

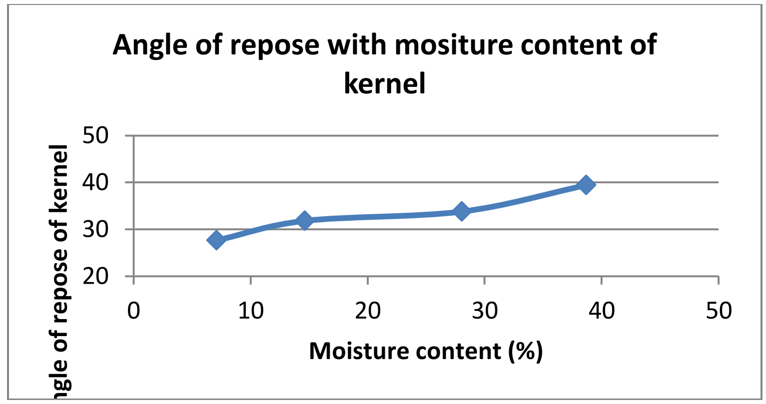


7(b)

Fig. 7. Moisture content vs. True density and Bulk density: (a) seed, (b) kernel

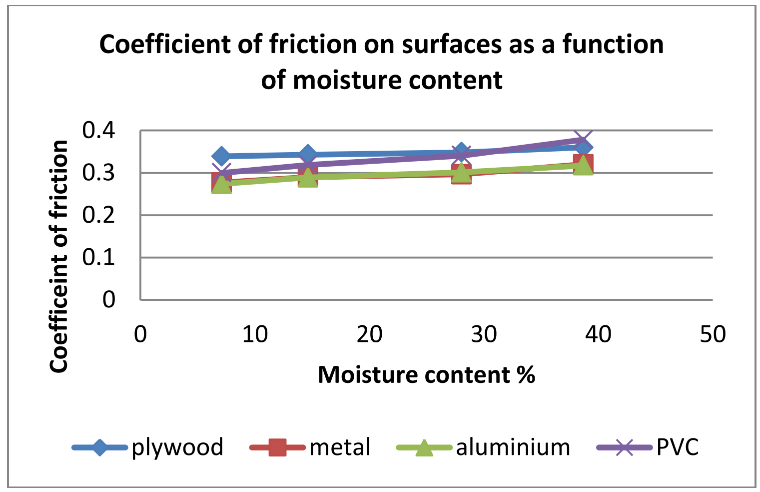


8(a)

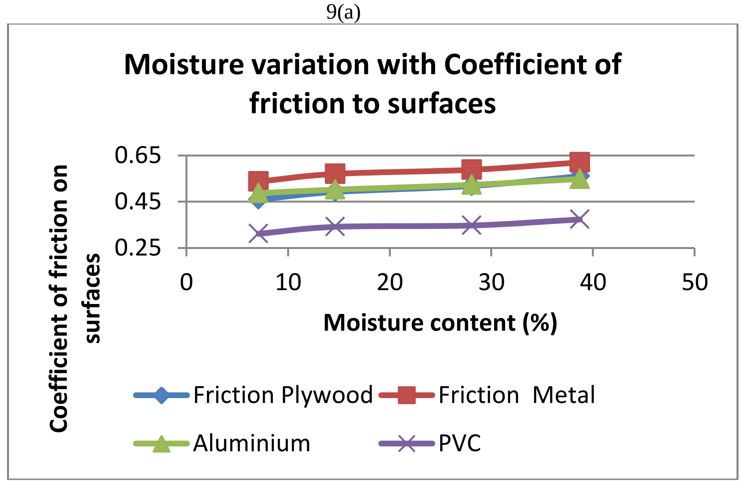


8(b)

Fig. 8. Moisture content and Repose angle: (a) seed, (b) kernel



9(a)



9(b)

Fig. 9. Variation of moisture and frictions on different surfaces: (a) seed, (b) kernel

TABLE I
Basic Dimensions, 1000 seeds mass, Arithmetic and Geometric diameters

Moisture Content (%)	Length (mm)		Thickness (mm)		Width (mm)	
	Seed	Kernel	Seed	Kernel	Seed	kernel
7.11	13.199 ± 0.464	11.2 ± 0.46	1.853 ± 0.287	1.378 ± 0.457	7.924 ± 0.143	6.424 ± 0.459
14.65	13.633 ± 0.193	11.433 ± 0.732	2.019 ± 0.093	1.808 ± 0.141	8.032 ± 0.126	7.053 ± 0.107
28.07	13.953 ± 0.275	11.853 ± 0.407	2.266 ± 0.107	2.054 ± 0.085	8.194 ± 0.484	5.794 ± 0.423
38.70	15.211 ± 1.036	12.691 ± 1.017	2.557 ± 0.272	2.383 ± 0.231	8.589 ± 0.530	6.989 ± 1.08

TABLE II
Bulk and true densities and Repose angle

Moisture Content (%)	Bulk Density (kg/m3)		True Density (kg/m3)		Repose angle (⁰)	
	Seed	Kernel	Seed	Kernel	Seed	kernel
7.11	414.006 ± 2.424	394.00 ± 2.424	901.515 ± 49.091	854.52 ± 50.707	23.661	27.66
14.65	424.076 ±4.921	401.80 ± 7.089	885.838 ± 40.253	836.84 ± 43.846	26.221	31.821
28.07	438.599 ± 0.819	429.20 ± 3.936	851.587 ± 22.505	840.59 ± 23.4	29.701	33.801
38.70	456.339 ± 6.092	436.34 ± 9.945	821.668 ± 37.131	813.67 ± 26.578	33.630	39.43

TABLE III
Moisture content and coefficient of friction on different surfaces

Moisture Content (%)	Coefficient of Friction Plywood		Coefficient of Friction Metal		Coefficient of Friction Aluminium		Coefficient of Friction PVC	
	Seed	Kernel	Seed	Kernel	Seed	Kernel	Seed	Kernel
7.11	0.3388	0.559	0.2767	0.637	0.2736	0.587	0.2999	0.548
14.65	0.3428	0.583	0.2900	0.580	0.2887	0.527	0.3189	0.449
28.07	0.3483	0.518	0.2964	0.456	0.3010	0.461	0.3408	0.347
38.70	0.3598	0.560	0.3198	0.620	0.3172	0.457	0.3782	0.475

TABLE IV
1000 seed/kernel mass, Arithmetic and Geometric mean diameters (seed and kernel)

Moisture Content (%)	1000 seed mass (g)		Arithmetic Mean Diameter (mm)		Geometric Mean Diameter (mm)	
	Seed	Kernel	Seed	Kernel	Seed	Kernel
7.11	95 ± 5	87± 3	7.6589	6.334	2.8429	2.668
14.65	105 ±1	92 ±6	7.8948	6.765	2.8718	2.728
28.07	118±2	95±6.9	8.1377	6.567	2.9010	2.701
38.70	130±1	108± 8	8.7857	7.354	2.9760	2.805

TABLE V
Surface area, Porosity and Sphericity of seed and kernel

Moisture Content (%)	Surface Area (mm^2)		Porosity (%)		Sphericity	
	Seed	Kernel	Seed	Kernel	Seed	Kernel
7.11	25.394	22.374	54.08	53.9	0.2154	0.2383
14.65	25.913	23.377	52.13	52.0	0.2107	0.2386
28.07	26.442	22.919	48.50	48.9	0.2079	0.2279
38.70	27.827	24.716	44.46	46.4	0.1956	0.2210