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Moisture Content and Its Influence on the Physical Properties of Tallow Seed for Efficient Threshing Machine Design

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ABSTRACT

The study investigated the moisture content on physical properties of tallow (Detarium senegalense) seeds. A randomized complete block design comprising of eight treatments with three replications were used. The initial moisture contents of the tallow seeds were determined before and after oven drying. Moisture conditioning was done in four moisture levels (19.65, 20.72, 21.90 and 22.81% dry basis). The findings showed that the length, width and thickness of the seeds ranged between 3.1 to 4.6, 2.7 to 4.2 and 1.2 to 2.3 mm, respectively, while the mean of geometric diameter and equivalent surface area ranged between 2.92 to 6.6 mm and 26.79 to 119.36 cm2, respectively. The results obtained in this study will provide useful information for mechanization of various unit operations involved in post-harvest processing and also in the development and evaluation of optimization parameters for efficient and effective processing equipment. Further studies on other engineering properties of tallow seed (thermal and aerodynamics) are needed to have comprehensive data in the study area.

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INTRODUCTION

Tallow commonly known as *Detarium senegalense* or Sweet detar is a species of plant in the Fabaceae family and a genus that is represented by eight species [Adenkunle *et al,* (2011)], However, only three species are found in West African forests; Detarium macrocarpum Harms, Detarium microcarpum Guillemin and Perrottet and *Detariumsenegalense*. These three species are very similar morphologically but appear to differ in ecological distribution (Elkamali, 2011).It grows naturally in the drier regions of West and Central Africa, (Germplasm (Germplasm Resources Information Network [GRIN], (2009).It mostly grows in dry forests (Kouyate, and Van-Damme, 2006). In Asia it grows in Indonesia and Singapore and in the Caribbean in Trinidad and Tobago.

Detarium senegalense is a medium sized to fairly large tree up to 35–40 m tall bole is branchless up to 12–15 m, straight or irregular, cylindrical, up to 60–100 cm in diameter, without buttresses but sometimes swollen at base bark, surface finely fissured, becoming scaly, grayish to blackish, with large, round lenticels, inner bark thickness, fibrous, red brown, with some sticky gum, crown large, dark green, with spreading branches.

Savannah type leaves glaucous beneath, flowers are creamy white in dense inflorescences. The tree has very large leafy crown and are bright green with common stalk 5-13 cm long [(Keay *et al,* 1989)].Different parts of the plant have been reported to possess medicinal value [(Kouyate, 2005)].It is known by various tribal names as ‘Ofo’ (Igbo), ‘Taura’ (Hausa) and ‘Ogbogbo’ (Yoruba) (Olapade and Peters, 2018). Among the Ibo tribe of south eastern Nigeria, the plant is believed symbolizing truth and honestly [(Akah *et al,* 2012)].Used the seed flour mainly as a soup thickener. A detarium meal were observed to elicit significant reduction in the plasma glucose

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levels of the human subjects investigated [(Onyechi *et al,*1998)].

The gum from the plant is reported to have shown promising anti diabetic effect in experimental rats [(Sowemimo *et al,* 2011)]. The greenish and sweet acidulous fruit pulp is edible, and can be eaten raw or cooked. It is also used to prepare sweetmeat or as an ingredient of ice cream. However, it may also be toxic, and caution is needed. The seed is oily and edible, and pounded seed is used as cattle feed. In Nigeria the seed flour is used traditionally as a emulsifying, flavouring and thickening agent in foods (Burkill, 1995) Used as a soup thickener. The bark is added to palm wine to accelerate fermentation and to make it bitterer. Seeds have been effective in controlling blood glucose levels in diabetic individuals [(Cisse *et al,* 2010)]. Also are taken as antidote against arrow poison and snake bites, also as emetic, insecticide, arachnicide and the smoke of burnt seeds as mosquito repellent. In spite of the economic importance of the African seed, there exists a dart of information about its physical and mechanical properties that could be used to design machines required for processing the seed [(Tashiwa *et al,* 2021)].Therefore, the aim of this study is to determine the moisture content dependent on physical properties of Tallow seed pod.

MATERIALS AND METHODS

The average diameter of tallow seed pod was calculated using the arithmetic mean and geometric mean of the three axial dimensions. The average diameter was determined by considering it as an effective diameter in terms of the thousand seed mass and the true density. Seeds was selected at random from the lot and their physical properties Plate 1 shows the tallow pod.

Plate 1: Tallow Pod

Moisture Conditioning

Distilled water was added to the sample and sealed in separate polythene bags which were kept in a refrigerator [Abba *et al.*2018)]; for even distribution of water to the seeds, plate 2 shows tallow moisture conditioning. The initial moisture content (dry basis) of the seeds were determined by grain metric method the samples until a relatively constant weight is reached [(Kawuyo *et al,* 2011)] and [(Adedeji *et al,* 2015)]. The quantity of distilled water to be added was calculated using equation

$$Q = \frac{W_i(M_f - M_i)}{(100 - M_f)} \quad (1)$$

Where;
Q = the mass of water added (kg)
W_i = the mass of sample (kg)
M_i = the initial moisture content of sample (%)
M_f = the final moisture content of sample (%)
The moisture conditioning was replicated three times and the mean values were calculated. The physico-mechanical properties were determined by using appropriate number of seeds for each of the properties.

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Plate 2 Tallow Moisture Conditioning

Determination of Size and Shape of Tallow Seed

This involves measuring the axial dimensions and calculation of mean diameters, sphericity and aspect ratio of tallow seed. The major (length), intermediate (width), and minor (thickness) dimensions of tallow seed was measured using a digital Vanier calliper of resolution 0.01mm. plate 3 show tallow pod measurement of size and shape At each moisture content level, 100 tallow seeds were used; twenty-five seeds measured and replicated four times. The means of the major, minor and the intermediate dimensions were calculated for further calculation of other engineering properties of tallow seed.

Arithmetic Mean Diameter

The arithmetic mean diameter of the tallow seeds were determined using the procedures reported by [(Anya, 2013)].

$$D_a = \frac{a+b+c}{3} \tag{2}$$

Where; a = major diameter (mm),b= minor diameter (mm),c = intermediate diameter (mm) of the seed pod

Geometric mean diameter

The geometric mean diameter ware determined from the physical dimensions (major diameter (a), minor diameter (b) and the intermediate diameter(c)) of the seeds. It was obtained from the relationship reported by [(Bup *et al.,* 2013)] and [(Orhevba *et al,*2013)]. as given in equation

$$D_g = (abc)^{1/3} \tag{3}$$

Where; a=Major diameter, b =Minor diameter, c = Intermediate diameter of the seed pod.

Plate 8: Measurement of Size and Shape

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Determination of True Density

The true density was determined using the toluene displacement method. About 10 seeds of known mass were lowered into a measuring cylinder containing toluene. The true density of a seed is defined as the ratio of the mass of a sample of a seed to the solid volume occupied by the sample. The seeds volume and their true densities were determined using the liquid displacement method. Toluene [(Aydin 2006; Bup *et al,* 2013)].

$$(\rho_t) = \frac{M}{V_t} \quad (4)$$

Where; M= Mass of the tallow seed pod (g), $v_t =$ Volume of toluene displaced (cm^3).

Determination of Angle of Repose

The angle of repose is the angle with the horizontal at which the material will stand when piled. This was determined by using a cylindrical container open at both ends. The cylinder was placed on a wooden table, filled with the seeds and raised slowly until it formed a cone of seeds [(Idowu *et al,* 2012)].

$$\phi = \tan^{-1}\left(\frac{2h}{d}\right) \quad (5)$$

Where; Ø= Angle of repose (^{0}), h= Height of the cone formed by the seeds (cm), d= Diameter of the base of the cone formed by the seed pod (cm)

Determination of Static coefficient of friction

The static coefficient of friction μ was determined for three structural materials (plywood, plastic and galvanised sheet). For this measurement, one end of the friction surface will be attached to an endless screw. The seed was placed on the surface and gradually raised by the screw (Sunmonu, 2015).

$$\mu = \tan\theta \quad (6)$$

Where; μ = coefficient of static friction, θ = the angle from the horizontal plane

Determination of Porosity

The porosity (ε) values were calculated from the values of true density and bulk density using the relationship as used by [(Bup *et al,* 2013)]. The relationship is given in equation 15

$$\left(1 - \frac{\rho_b}{\rho_t}\right) \times 100 \quad (7)$$

Where;

$\rho_b =$ Bulk density (kg/m^3)

$\rho_t =$ True density (kg/m^3)

Determination of surface Area of agricultural Materials

Altuntas *et al*. (2006); Galedar *et al*. (2008); and calculated the surface area of agricultural materials in terms of its geometric mean diameter based on Jain and Ball's equations 16

$$A_s = \pi D g^2 \quad (8)$$

Where;
A_s = surface area (mm^2)
Dg = geometric mean diameter (mm).

Determination of Bulk Density of the Agricultural Materials

Bulk and true densities are useful in sizing grain hoppers and storage facilities [(Sahay and Singh, 2001)]. Densities (true and bulk) influence the rate of heat and mass transfer of moisture during aeration and drying processes [(Seifi and Alimardani, 2010)]. Density generally is useful in the mathematical conversion of seed mass to seed volume [(Asoegwu *et al*, 2006)]. It is also a good indicator of kernel filling during growth in addition to its use in breakage susceptibility prediction, and it has been employed in determining the size of packaging box [(Hassan-Beygi *et al*, 2009)]. Several researchers calculated

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the bulk density of agricultural materials [(Razavi *et al,* 2008)].

In order to determine the bulk density for Tallow seed, a container was filled with Tallow seed sample in excess. After filling the container of 1000 ml, a flat ruler was passed across the top surface of the container to remove excess seeds. The sample was not compacted in any way. The container was weighed using an electronic balance (Adventurer AR3130) with a precision of 0.001g. The weight of the Tallow seeds was obtained by a difference, plate 10 show tallow pod bulk density determination. The process was replicated twice and the bulk density was calculated from the following relationship in equation 19 [(Bup *et al,* 2013)].

Bulk density (ρb) = m/v (9)

Where;
m = mass of Tallow seed (g)
v = the volume of the container used (cm^3).

Sphericity of the Agricultural Materials

The sphericity value obtained by calculation in terms of the axial dimensions of seed, kernel, or nuts is affected by the formula used [(Seyed, 2007)]. In their research on the physical properties of watermelon seeds equations 20

$$\emptyset = \left(\frac{B(2L-B)}{L}\right)0.333 \qquad (10)$$

Where;
$\emptyset$ = Seed sphericity (mm)
L= Major dimension (mm)
B= Seed Intermediate (mm)

RESULTS AND DISCUSSION

The averages of length, width and thickness were found to be 3.6, 3.3 and 1.5 mm respectively. The findings showed that the length, width and thickness of the seeds ranged between 3.1 to 4.6, 2.7 to 4.2 and 1.2 to 2.3 mm, respectively, while the mean of geometric diameter and equivalent surface area ranged between 2.92 to 6.6 mm and 26.79 to 119.36 cm^2 respectively. These values may be used to determine the size of aperture as well as the size of the machine components. The mean value of the sphericity was 0.85 and 0.75.

Table 1. Analysis of Variance (Mean Square) on Force of Tallow Seeds at Peak, Break and Yield (N)

Sources of Variation	df	Peak	Break	Yield
Replication	2	6230702.9*	1487430.881*	537141.714*ns*
Treatment	7	635617.96*ns*	6955730.236*	344018.438*ns*
Orientation	1	4208..28*	42942957.62*	11146692.81*
Moisture Content (M.C)	3	1407796.594*	16020909.71*	962510.014*
M.C*Orientation	3	3710497.603*	46565266.13*	1950344.566*
Error	14	254995.5	36332072.2	258361.9

Effect of Moisture Content on True Density

The true density of tallow seed varied from 821.90 to 832 kg/m3 when the moisture content was increased from 19.65 to 22.81% (dry basis) as shown in Figure 1. Also, the true density values linearly increased with increase in moisture content. However, there was no significant increase in the volume of the seed with moisture content. A similar increasing trend in true density of other agricultural materials has also been observed by Aydin (2007) on peanut and its kernel, Balasubramanian (2001) on raw cashew nut, [Singh *et al.* (2010)]; on barnyard millet grain and kernel, [Kiani *et al.* (2008)]; on red bean and [Fathollahzadeh *et al.* (2008)]; on apricot kernel. Moreover, the obtained values for the true density

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indicated that tallow seed will sink in water between a moisture content of 19.65 and 22.81% dry basis. This could be exploited in separating unsinkable foreign materials from the seed. The model equation and coefficient of determination R^2 are expressed as;

$$Y = 0.0438MC + 0.4107 \quad R^2 = 0.97 \qquad (11)$$

Effect of Moisture Content on Angle of repose

Figure 4 showed the variation of the static angle of repose with seed moisture content increase from 19.65 to 22.81`%. The values were found to increase from 31.6 to 37.8° with an increase with moisture content from 19.65 to 22.81%. The increasing trend of angle of repose with moisture content occurs because the surface layer of moisture surrounding the particle holds the aggregate of seed together by the surface tension [(Pradhan *et al,* 2008)]. The values of the angle of repose (θ) and coefficient of determination for tallow seeds bear the following relationship with its moisture content.

$$Y = 6.3381MC – 93.711 \qquad R^2 = 0.94 \qquad (12)$$

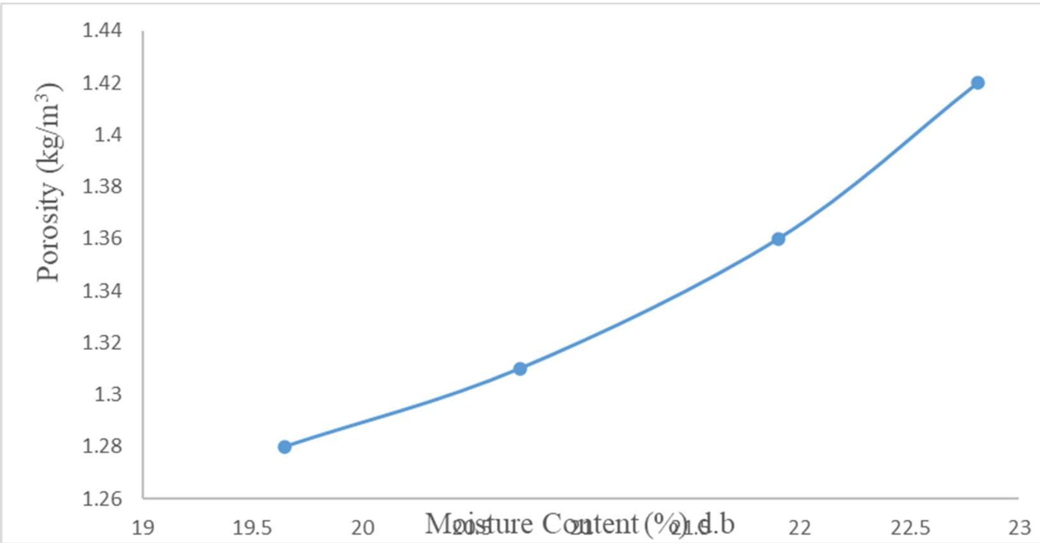

Figure 1: Relationship between Moisture Content (%) and Porosity (kg/m³)

Effect of Moisture Content on Coefficient of Friction

The static coefficient of friction of tallow seeds obtained experimentally on three structural surfaces in moisture range of 19.65 to 22.81% (db). Figure 5, shows that the static coefficient of friction increases as moisture increase on galvanised steel and plywood and decreases on plastic. The highest value was observed on plywood and the lowest on galvanised steel. The increase might be due to the increase in adhensive force which made it difficult to move on the surfaces and the decrease due to increase in cohesive force more polished surface of plastic which made it easy to move on. This result is in agreement with [Abba *et al.* (2018)]; Fadavi (2013) for wild pistacho nuts, [Idowu *et al.* (2012)]; for sandbox seed and Hasbavi (2013) for Iranian okra seeds. The model equation and coefficient of determination R^2 are expressed as;

$$CFgs = 0.0438MC + 0.4107 \quad R^2 = 0.97 \qquad (13)$$

$$CFpw = 0.1446MC – 1.0108 \quad R^2 = 0.72 \qquad (14)$$

$$CFpl = -0.1738MC + 4.9769 \quad R^2 = 0.99 \qquad (15)$$

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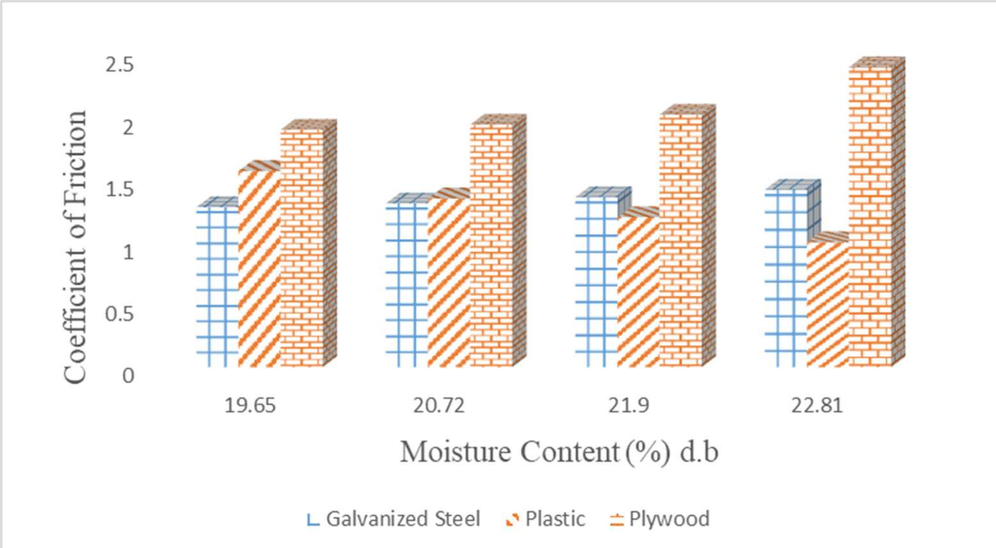

Figure 2. Relationship between Moisture Content (%) and Coefficient of Friction

CONCLUSION

All the axial dimensions increased linearly with increase in moisture content from 19.65 to 22.81%. The geometric mean diameter, sphericity and surface area increased with increase in moisture content. However, there is a decrease in porosity and bulk density as the moisture increases

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