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Engineering Properties of Tiger Nut Seeds Relevant to the Design of Cleaning and Sorting Machine

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***Abstract*— In this study, selected physical properties (size and shape, volume and density, surface area, weight, sphericity, coefficient of friction, angle of repose, as well as terminal velocity) of the brown type of tiger nut seed were determined using standard procedures. The average values of the surface area (206.12 mm^2), geometric mean diameter (7.29 mm), sphericity (74.39 %), coefficient of friction for the three materials used were 0.37, 0.32 and 0.26 respectively (0.32), the mean values of the angle of repose of tiger nut seed for wood (20.5°), glass (17.°5) and metal (14.4°) and terminal velocity of 17.60 mm/s of the tiger nut seed at moisture content of 17 % (wb) were used in this study. These data are important for designing of cleaning and sorting machines of Tiger nut seeds.**

Keywords*— coefficient of friction, spherecity, terminal velocity, tiger nut

I. Introduction

Tiger nut (Cyperus esculantus) is a grass like plant which produces rhizomes from the base and tubers that are somewhat spherical and ranked among the oldest cultivated plant in Egypt. In Nigeria, it is commonly known as "Aya" in Hausa, "Ofio" in Yoruba, and "Akiausa" in Igbo. Tiger nut is one of the cash crops which have not been given due recognition and patronage possibly because not many people know its nutritional benefit. According to (1), it is a known plant food that is common in West Africa especially Northern Nigeria. It is one of the best nutritional crops that can be used to augment the diet of humans (2). Tiger nut produces high quality oil about 25.5 % of its content and protein about 8 % of the nut (3). Other uses of tiger nut are: it has a fairly good essential amino acids composition similar to olive oil and castor seeds and is a potential oil crop for the production of bio-diesel. It is also used in medicine and perfume production as well low fat food and has low anti-nutritional factors especially polyphenols (4; 5; 6).

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Spain is the highest producer of tiger nut with 3,000 metric tons per annum followed by USA and Egypt with 2,700 and 2, 000 metric tons respectively. In Africa, Niger Republic is the major producer with 125 metric tons followed by Ghana with 50 metric tons (6). In Nigeria, the production is concentrated in the Northern parts of the country amounting to 36.3 metric tons. In Nigeria, despite the huge economic importance of tiger nut crop, the crop is yet to assume its full potentials. Upon the ever increasing application, little information is available on the basic engineering properties of this material, particularly in Nigeria. This is because there is no or little information available on the basic engineering properties or processing facilities for tiger nut seed (7). It is also essential to determine the engineering properties of oilseeds (for example tiger nut seed) for proper design of agricultural machinery. Therefore, the knowledge of the engineering properties of tiger nut is important in the design of agricultural equipment for its processing. As such this study is to determine some selected engineering properties of tiger nut seeds: (shape, size, colour, seed weight, volume, particle density, bulk density, porosity, surface area, angle of repose and compressive strength).

II. Materials and Methods

A. *Selection of Materials*

The brown type of tiger nut seed was selected as material for this investigation. The seeds were obtained from a local market in Minna, Niger State, Nigeria.

One thousand samples of tiger nut seeds were randomly selected and used in determining the following physical and aerodynamic properties of the tiger nut seeds at 17 % moisture content (w.b).

B. *Determination of the Physical Properties*

The physical properties of the tiger nut relevant to design of agricultural machinery (shape, size, volume and density, surface area, specific gravity, weight, coefficient of friction, angle of repose and terminal velocity) were determined using standard engineering principles (8; 9; 10; 11; 12; 13; 14).

III. Results and Discussion

The results obtained from this investigation are shown in Tables 1 – 3.

A. *Physical Properties of tiger nut seed*

The results of the physical properties of tiger nut seeds determined are presented in Table 1. The three principle mean dimensions of tiger nut seed measured are 9.01, 6.80 and 5.26 mm for the major, intermediate and minor diameters respectively while the geometric mean diameter is 7.29 mm at the 17 % moisture content (w.b) and that fall within the size range stated by Abano and Amoah (15) for other grains and seed. The mean value of the spherecity of tiger nuts was found to be 74.39 %. This result shows that tiger nut seed are spherical and means it can roll freely (16). Also the average value of the surface area of tiger nut seed at that 17 % (wb) moisture was found to be 206.12 mm^2. This value is also closed to that obtained by (1). Also the mean volume, density and the weight of 1000 tiger nut seeds were found to be 0.000006 m^3, 1.4 x 10-9 kg/m^3 and 429.63 g respectively.

B. *Frictional Properties of Tiger Nut Seed*

The results of the coefficient of friction of tiger nut seed determined using three structural Surfaces (wood; glass and metal) are presented in Table 2. The mean coefficient of friction for the three different materials used which were 0.37, 0.32 and 0.26 respectively. This conformed well to the findings of (17; 11; 18; 16); (16; 19) that used a similar technology for other grains and seed.

C. *Angle of Repose of Tiger Nut Seed*

The results of the determined angle of repose of tiger nut seeds are presented in Table 3. It can be observed that the mean values of the angle of repose of tiger nut seed were for wood (20.5°), glass (17.5°) and metal (14.4°).

D. *Summary of the physical and Aerodynamic properties of the tiger nut seed*

The summary of the physical and aerodynamic properties of tiger nut seed are presented in Table 4. The terminal velocity of the tiger nut seed nut at 17 % moisture content (w.b) is 17.60 mm/s. This result also conformed well to that of (15). These parameters are important in designing cleaning and sorting machine for tiger nut seeds.

TABLE I. MEAN VALUES OF PHYSICAL PROPERTIES OF TIGER NUT SEED

GROUP	Major Ɵ (D_1 mm)	Interm-ediate Ɵ (D_2 mm)	Minor Ɵ (D_3 mm)	Geom-etric mean Ɵ (D_g mm)	Sphe-recity Ø%	Surface Area S(mm^2)	Volume (mm^3)	Density kg/mm^3
A	9.06	6.90	5.16	6.85	75.55	147.41	$1.759x10^{-6}$	$3.126x10^{-9}$
B	8.27	7.31	6.78	7.41	89.64	172.50	$1.116x10^{-6}$	$5.37x10^{-9}$
C	9.69	5.65	2.58	5.20	53.66	85.28	$6.500x10^{-6}$	$6.839x10^{-10}$
D	8.91	6.82	4.96	6.69	75.11	140.61	$1.936x10^{-6}$	$2.066x10^{-9}$
E	9.77	7.24	5.92	7.47	76.42	175.30	$1.240x10^{-6}$	$4.599x10^{-9}$
F	8.91	7.78	7.04	7.86	88.18	206.12	$9.611x10^{-6}$	$6.451x10^{-10}$
G	8.24	7.83	7.51	7.84	95.12	193.10	$1.028x10^{-6}$	$5.450x10^{-9}$
H	8.73	7.95	7.08	7.89	90.20	195.10	$9.699x10^{-6}$	$5.465x10^{-10}$
I	8.74	6.99	7.93	7.84	89.68	193.10	$9.39x10^{-6}$	$4.729x10^{-10}$
J	8.24	7.83	7.51	7.84	95.12	193.10	$9.132x10^{-6}$	$5.913x10^{-10}$
Mean	9.01	6.80	5.26	7.29	74.39	206.12	0.000006	

TABLE II. Mean values of Coefficient of Friction of Tiger Nut (Using three Structural Surfaces)

No of Trial	Vertical Height (H)cm	Radius of Spread (L) cm	Tan $\theta = \frac{H}{L}$	$\theta = Tan^{-1}$
1	3.0	6.0	0.50	25.5
2	2.7	5.6	0.48	25.6
3	2.7	5.4	0.50	26.5
4	3.0	5.8	0.52	27.5
5	2.5	5.8	0.43	23.3
6	2.8	5.6	0.50	26.5
7	2.6	5.3	0.49	26.1
8	2.6	5.4	0.48	25.6
9	2.8	5.4	0.52	27.5
10	3.0	6.0	0.50	26.5
Minimum				23.3
Maximum				27.5
mean value				25.4

TABLE III. Angle of Repose of Tiger Nut Seed

No. of replication	Wood Surface	Glass Surface	Metal Surface
1	22.0	18.0	15.0
2	21.5	19.0	15.8
3	20.0	17.0	15.2
4	21.0	16.5	14.0
5	21.5	17.5	13.5
6	19.5	18.6	13.0
7	19.0	16.0	15.0
8	20.0	17.0	15.1
9	20.5	16.0	15.0
10	21.0	17.0	15.2
Minimum	19.0	16.0	13.0
Maximum	22.0	19.0	15.8
mean value	20.5	17.5	14.4
$\mu = tan\theta$	0.37	0.32	0.26

TABLE IV. The summary of the Physical and Aerodynamic Properties of tiger nut seed

S/No.	Properties		Value
1	Mass of one piece of tiger nut seed (M)		4.3 x 10^{-4}, g
2	Diameter	Major	9.01 mm
		Intermediate	6.80 mm
		Minor	5.26 mm
3	Density (ρ) of tiger nut seed		1.4x10^{-9} kg/m^3
4	Volume (Vm) of tiger nuts seed		0.6x10^{-6} mm^3
5	Moisture content of tiger nut seed		17 % (wb)
6	Coefficient of friction (μ) (wood; glass; metal)		0.37; 0.32; 0.26
7	Angle of repose of tiger nut seed		25.4°
8	Spherecity of tiger nut seed		74.39 %
9	Surface area of tiger nut seed		206.12 mm^2
10	Specific gravity of tiger nut seed		9.3
11	Terminal velocity of tiger nut seed		17.60 mm/s^2

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