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Determination of some Selected Engineering Properties of Tiger Nut (*Cyperus Esculentus*)

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Abstract: *This study examines some engineering properties of tiger nuts in order to provide valuable insights for their application in food processing and storage. Physical, mechanical and thermal properties of tiger nut were determined using different instruments. The average dimensions of tiger nuts were recorded as 11.40 mm in length, 8.70 mm in width, and 6.40 mm in thickness, contributing to their uniform shape. The geometric mean diameter (GMD) was 8.58 mm. it has a sphericity of 0.75% and an aspect ratio of 76.33%, indicating relatively uniform and spherical shapes. With a surface area of 766.68 mm² and a volume of 329.59 mm³. The true density and bulk density were 1.18 kg/m³ and 0.59 kg/m³, respectively, indicating the density and compactness of the nuts. The porosity was measured at 50.00%, suggesting a substantial proportion of void spaces that influence airflow and moisture retention. The moisture content of tiger nuts averaged 9.60%, with a slight variation ranging from 9.20% to 10%, beneficial for storage stability. They exhibited moderate water absorption capacity, with a coefficient of variability of 7.509%, indicating consistent behaviour across samples. The average angle of repose was 23.58 degrees, showing that piles of tiger nuts remain stable at slopes shallower than this angle. Variations in the angle of repose, with a standard deviation of 20.80 degrees, could be attributed to factors such as size, shape, and moisture content. Overall, the findings indicate that tiger nuts have desirable properties for food industry applications, including low moisture content, uniform size and shape, moderate water absorption capacity, and significant porosity for moisture retention and airflow. These characteristics support prolonged storage and efficient processing, offering valuable information for agricultural practices, equipment design, and product development.*

Keywords: *Tiger Nuts, Engineering Properties, Geometric Mean Diameter, Food Processing, Storage Stability*

INTRODUCTION

Tiger nut (*Cyperus esculentus* L.) belongs to the sedge family that is cultivated in Africa, southern Europe, and the United States of America, Tetteh & Ofori (1998); Bamishaiye & Bamishaiye (2021). It is most found in wet marshes, edges of water bodies such as streams, ponds where it grows in clusters. Tiger nuts are cultivated on a small scale by rural farmers in the northern states of Nigeria, Oladele *et al,* (2009). Tiger nuts have small tubers that are edible, sweet, nutty, flavoured tubers which contain protein, carbohydrate, sugars, vitamins and lots of oil and fiber, FAO (1988); Belewu & Abodunrin (2008). It has variety of uses which include: beverage, milk or fermented milk product (such as yoghurt), flour, edible oil, honey, jam, beer, liqueur, chocolate, candies, soap, and as feed source, Saleh (2021). Tiger nuts is mostly used in the production of non-alcoholic beverages that are traditional in West Africa - *Kunnun Aya,* Saleh (2021). They are also consumed as snack food and their flour is used in baking, Codina-Torella *et al.* (2015). In Nigeria, tiger nut is available in fresh, semi-dried and dried form in the markets where it is sold locally and consumed even uncooked. Because of its nutritional content and sole beneficial properties, tiger nut is believed to contain all the functional compounds needed for a balanced diet Chukwuma *et al.* (2010).

The physical properties of tiger nuts, including size, shape, density, and porosity, have implications for their handling, processing, and storage. Previous studies have highlighted variations in these properties among different tiger nut (yellow varieties). The mechanical properties of tiger nuts, such as hardness, on the other hand, are crucial for designing machinery and equipment for processing and harvesting. Various research works have addressed the measurement and significance of these properties. (Bamgbose, 2003). The thermal properties of tiger nuts, including specific heat and thermal conductivity, impact their behaviour during heating processes, such as roasting and drying. Investigating these properties can improve processing methods (Bamgbose, 2003 and Saleh *et al*., 2023). The objectives of this study, therefore, arise due to the growing need to provide the scientists, engineers and food processors with the properties of tiger nut because of its economic and industrial importance. Knowledge of these properties will assist in the long run while processing and handling the crop.

MATERIALS AND METHODS

About The physical properties of tiger nuts determined include size, shape, density, and porosity, have implications for their handling, processing, and storage. Understanding the mechanical properties of tiger nuts, such as hardness, is crucial for designing machinery and equipment for processing and harvesting. Various research works have addressed the measurement and significance of these properties (Bamgbose, 2003; Saleh & Jamiu, 2022; Saleh *et al.*, 2022). Thermal properties of tiger nuts, such as specific heat and thermal conductivity, impact their behaviour during heating processes (roasting and drying, for example). Investigating these properties can improve processing methods (Bamgbose, 2003; Saleh *et al.*, 2023).

2.1 Materials

The material used in determining some engineering properties of tiger nut includes: tiger nut; Venire calliper (Olsen, Model. No: 3408), measuring cylinder, hardness (digital grain hardness tester model AGW,) Moisture Content (Oven, Model (DHG), weighting scale model, No: 5350)

2.2 Preparation of the Samples

The Tiger Nuts (yellow variety) were purchased from Samaru Market of Sabon Gari local government in Kaduna state and kept in cooled bags during transportation to the laboratory. Tiger nuts were cleaned manually to remove all foreign matter such as dust, dirt, stones and chaff as well as immature and broken seeds. The initial moisture content of the nut was determined by oven drying at 105 ±1 °C for 24 hr. **(**Suthar and Das, 1996**).**

2.3 Dimensions

To determine the linear dimensions of the tiger nuts, one hundred Tiger nuts was randomly selected. For each nut, the three principal dimensions, namely length (major diameter), width (minor diameter) and thickness (intermediate diameter) was measured using Vernier caliper having the least count of 0.001 mm. The length L was defined as the distance of the Tiger Nuts bottom to the top. Width (W) was defined as the widest point to the point measurement taken parallel to the faces of the nut. Thickness (T) was defined as the measured distance between the two nuts faces as described by Pordesimo *et al*., (1990). The geometric mean diameter of the seed was calculated using (Mohsenin, 1980).

2.4 Determination of Physical Properties of Tiger Nut

The Physical properties that were determined include: Axial dimension, Geometric mean diameter, square mean diameter, Equivalent mean diameter, Arithmetic mean diameter, Sphericity, Surface area, Mass of one thousand seeds, Density, Porosity, Volume and Static

2.5 Axial Dimension

100 Tiger Nuts was randomly selected from the bulk sample and used for the determination of the axial dimensions which are: Length (L), Width (W) and the Thickness (T) of the tiger nut using a digital venire. (Olsen, Model. No: 3408).

2.6 Arithmetic Mean Diameter (Da)

The arithmetic mean diameter was evaluated using the following relationship (Mohsenin, 1980)

$$D_a = \left(\frac{L+W+T}{3}\right) \quad (1)$$

Where,

L= is the length of the specimen in mm
W = is the width of specimen in mm and
T = is the thickness of the specimen in mm

2.7 Geometric Mean Diameter (Dg)

The equivalent mean diameter was evaluated using the following relationship given by (Mohsenin, 1980) below;

$$D_g = (L\ W\ T)^{1/3} \quad (2)$$

Where,
L is the length of the specimen in mm,
W is the width of the specimen in mm and
T is the thickness of the specimen in mm

2.8 Sphericity

The sphericity was computed using the formula given by (Mohsenin, 1980)

$$\emptyset = \frac{(L\,W\,T)^{1/3}}{L} \quad (3)$$

Where,
$\emptyset$ = Sphericity, L= length of the specimen in mm, W= width of the specimen in mm and T= is the thickness of the specimen in mm

2.9 Surface Area (A)

The frontal area of the specimen was determined using the formula below (Mohsenin, 1980);

$$A = \left(\frac{\pi D_g^2}{4}\right) \quad (4)$$

Where,
A = is the surface area of the specimen in mm^2,
D_g = is the geometric mean diameter of the specimen in mm (Mohsenin, 1980)

2.10 Volume

Archimedes principle is very useful for calculating the volume of a material or particles that does not have a regular shape. The oddly shaped object can be submerged and the volume of the fluid displaced is equal to volume of the material or particles.

The volume of the specimen will be determined using Archimedes Principle as described by Oje (1993) and Isiaka *et al;* (2012). For agricultural products, volume can be calculated using the geometric measurement as given (Mohsenin, 1980);

$$V = \frac{4}{3}(\pi\ LW^2) \quad (5)$$

Where L= length of specimen, W= width of the specimen and V = volume of the specimen

2.11 True Density

The true density was determined using liquid displacement method, (Mohsenin, 1980). A Tiger Nutssample of 5g was submerged in water in a measuring cylinder having an accuracy of 0.1 ml, the increased in volume due to sample was noted as true volume of sample which will be used to determine the true density of the sample (Mohsenin, 1980)

$$Ps = \frac{Weight\ of\ sample\ (Kg)}{Volume\ of\ distilled\ water\ displaced\ (M3)} \quad (6)$$

Where, Ps = true density (kg/m^3), M = weight of the sample (kg), V= volume of water displaced (m^3)

2.12 Bulk Density

The bulk density is the ratio of the mass sample of the seeds to its total volume which is calibrated in kg/m³. The bulk density of the specimen nuts at the desired moisture content was determined by filling a 100 ml container with the seeds, then weighing the contents on an electronic balance. Bulk density was determined using equation (vii) as used by Deshpande *et al.*, (1993), Gupta and Das (1997), Konak*et al.* (2002).

$$Pb = \frac{M}{Vb} \quad (7)$$

Where, ρb = bulk density, M = total of the specimen in 100 ml container and V_b = total volume of the specimen

2.13 Porosity

Porosity is the space between detrital Tiger Nuts. Micro porosity exists as small pores (less than 2 µm) commonly associated with detrital and antigenic clay mineral. The porosity was calculated from the values of bulk and the true density using the relationship below. The porosity were determined using equation (8) as used by Mohsenin (1970).

$$P = \frac{\rho t - \rho b}{\rho t} x100 \quad (8)$$

Where, P = porosity in (decimal or percentage), ρt = true density in kg/m³, ρb = bulk density in kg/m³.

2.14 Angle of Repose

The angle of repose is the characteristics of the bulk material which indicates the cohesion among the individual sesame (Wandkar *et al.*, 2012). The higher the cohesion, the higher the angle of repose. This was determined by using an open- ended cylinder of 15 cm diameter and 30 cm height. The cylinder was placed at the center of circular plate having a diameter of 70 cm and was be filled with tiger nut. The cylinder was raised slowly until it formed a cone on the circular plate. The height of the cone was recorded. The angle of repose was used in equation (ix) as used by (Wandkar et al., 2012).

$$\theta = \tan^{-1}(\frac{2h}{dc}) \quad (9)$$

Where, θ = is the angle of repose,
h = is the height of pile,
dc = is the diameter of cone

2.15 Coefficient of Static Friction

Coefficient of static friction is the friction force between two materials when neither of the material is moving. A value of one for coefficient static friction means the frictional force and normal reaction force are equal. The coefficient of static friction was determined with respect to three surfaces namely wood, metal sheet and plastic. These were selected because they are common materials used for handling and processing of Tiger Nuts. It was determined using procedures described by Razavi and Milani (2006) and Ghasemi et al. (2008). The angles for the coefficient of friction for Tiger Nuts were determined using the inclined plane method. This will be done by placing each of the surface on the incline plane, pushing a Tiger Nutson it and then beginning to lift the incline plane slowly and carefully until the seed started sliding. The angle of inclination (θ) will be measured by calibrating protractor attached to side of the inclined plane, taking the tangent of the angle of inclination at which the Tiger Nuts begins to slide on the surface gives the coefficient of static friction according to the method as described by (Ogunsina and Bamgboye, 2003). Coefficient of static friction was determined using equation (10).

$\mu = \tan \theta$ (10)

Where, μ= coefficient of static friction when neither of the specimens is moving, θ = frictional angle which is usually between zero and one.

2.16 Moisture Content

The moisture content of Tiger Nuts was determined by an oven drying method using a standard procedure as recommended by Suthar and Das (1996) 105°C ±1 for 24h. The moisture content was calculated using equation (11) [Isiaka *et al.*, 2012].

$$MC_{db} = \frac{M1-M2}{M1} \quad (11)$$

Where MC_{db}= the moisture content on (dry basis) of the specimen,
$M_{1=}$ is the initial mass of the specimen before being oven dried and
$M_{2=}$ is the final mass of the specimen after being oven dried

2.17 Determination of Mechanical Properties of Tiger Nuts

Mohsenin (1963) defines mechanical properties of a material as those properties which have to do with its behavior under applied forces.

2.18 Data Analysis Tools

The following data analysis tools were used to analyse the data collected;
Statistical software: Microsoft excel software was used to calculate the mean, standard deviation, and coefficient of variation for the data. It was also be used to compare the data to other data sets.

RESULTS AND DISCUSSION

3.1 Size and Shape

Results obtained (Table 1) shows that Tiger nuts exhibited average dimensions of 11.40 mm (length), 8.70 mm (width), and 6.40 mm (thickness). These dimensions contribute to their characteristic shape and size uniformity.

Table-1 Statistical Analysis of Some Engineering Properties of Tiger Nut

Physical properties	Unit	Sample size	Minimum value	Maximum value	Mean	Standard deviation	Variance	Coefficient of variability
Moisture content	%	3	9.20	10	9.6000	0.32660	0.107	3.402083333
Length	Mm	100	11.00	11.80	11.4000	0.32660	0.107	2.864912281
Width	Mm	100	8.60	8.80	8.7000	0.8165	0.007	9.385057471
Thickness	Mm	100	6.10	6.70	6.4000	0.24495	0.060	3.82734375
GMD	Mm	100	8.07	9.09	8.5833	0.41644	0.173	4.851746997
Sphericity	%	100	0.70	0.80	0.7500	0.04082	0.002	5.442666667
Aspect Ratio	%	100	74.30	78.40	76.3333	1.67398	2.802	2.192987857
TKW	G	3	750	783.38	7.66.683	13.62733	185.704	1.777439959
Surface area	mm^2	100	222.60	240.78	766.6833	7.42195	55.085	0.968059432
Volume	mm^3		312.45	346.73	329.5900	13.99475	195.853	4.246108802
Rmin	Mm	100	4.15	4.75	4.4500	0.24495	0.060	5.504494382
Rmax	Mm	100	51.61	60.09	55.8500	3.46195	11.985	6.198657117

Angle of repose	0	3	42.24	46.42	44.3300	1.70648	2.912	3.849492443
Bulk density	Kg/m³	3	0.52	0.66	0.5900	0.05715	0.003	9.686440678
True Density	Kg/m³	3	1.09	1.27	1.1800	0.07348	0.005	6.227118644
Porosity	%	3	41	59	50.0000	7.34847	54.000	14.69694
WMRS	Kg	3	144.40	162.10	154.8750	8.75457	76.642	5.652668281
Finess Modulus	Mm	3	0.2336	0.2449	0.241475	0.0053705	0.000	2.224039756
Uniformity Index	Mm	3	0.1511	0.1670	0.157750	0.0079668	0.000	5.050269414
MC	%	3	12	14	12.7500	0.95743	0.917	7.509254902

*TKW: Thousand Kernel Weight, WMRS: Water Absorption and Moisture Retention Studies, MC: Moisture Content, GMD: Geometric Mean Diameter

3.2 Geometric Mean Diameter (GMD)
The GMD was determined to be 8.5833 mm, indicating the average size of the tiger nuts in a geometric sense.

3.3 Sphericity and Aspect Ratio
Tiger nuts displayed a sphericity of 0.75% and an aspect ratio of 76.3333%, suggesting relatively uniform and spherical shapes.

3.4 Surface Area and Volume
With a surface area of 766.6833 mm² and a volume of 329.5900 mm³, tiger nuts possess adequate surface area for moisture exchange and volume for nutrient storage.

3.5 True Density and Bulk Density
The true density was determined to be 1.1800 kg/m³, while the bulk density was found to be 0.5900 kg/m³. These values indicate the density and compactness of the tiger nuts, which are important for processing and storage considerations.

3.6 Porosity
Tiger nuts exhibited a porosity of 50.0000%, suggesting a significant proportion of void spaces within the structure, which influences airflow and moisture retention.

3.7 Moisture Content and Water Absorption Characteristics
A. Moisture Content

Results obtained also shows that the average moisture content of tiger nuts was found to be 9.60%, indicating a relatively low moisture content, which is beneficial for storage stability. Moisture Content Variation The moisture content ranged from 9.20% to 10%, indicating slight variability within the samples. This variation could impact storage stability and processing methods.

B. Water Absorption Capacity

Tiger nuts demonstrated a moderate water absorption capacity, with a coefficient of variability of 7.509254902%, suggesting consistent behavior across different samples.

3.8 Frictional Properties

The average angle of repose across the samples is 23.58°s. This indicates that, on average, piles of tiger nuts will remain stable at slopes shallower than 23.58°. There is some variation in the angle of repose between samples, with a standard deviation of 20.80°. This variation could be due to several factors, such as the size, shape, and moisture content of the tiger nuts. The results obtained also indicate that tiger nuts possess desirable physical and mechanical properties for various applications, including food processing and storage. Their low moisture content, uniform size and shape, and moderate water absorption capacity make them suitable for prolonged storage and processing into various products. The observed porosity suggests potential for moisture retention and airflow, contributing to product quality and shelf life. Overall, these findings provide valuable insights for agricultural practices, equipment design, and product development within the food industry. This analysis highlights the key findings and implications of the engineering properties of tiger nuts based on the provided data.

CONCLUSION

The study of the engineering properties of Tiger nuts yields valuable insights into their suitability for various applications in the food industry. The observed characteristics contribute to their marketability, processing efficiency, and versatility, underscoring their potential as a valuable commodity with diverse culinary and industrial applications. The optimization and utilization of the engineering properties of Tiger nuts hold promising prospects for enhancing their value and market potential, thereby contributing to the sustainable growth and development of the Tiger nut industry.

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CONFLICT OF INTEREST

The authors declare no competing interest

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