DETERMINATION OF SOME PHYSICAL AND CHEMICAL PROPERTIES OF TIGER NUT (*Cyperus esculentus*)

BY

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BEING A FINAL YEAR PROJECT SUBMITTED IN PARTIAL FULFILMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) AGRICULTURAL AND BIORESOURCES ENGINEERING FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

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DECLARATION

I hereby declare that this project is a record of a research work that was undertaken and written by me. It has not been presented before for any degree, diploma or certificate at any University or Institution. Information derived from personal communication, published and unpublished works of others were duly referenced in the text.

Salaol -- 21/11/2008 ----------------------------

Salawudeen Suleiman Date

CERTIFICATION

This project entitled "Determination of some physical and chemical properties of Tiger Nut" by Salawudeen Suleiman meets the regulations governing the award of Bachelor of Engineering (B.ENG) of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is whole heartedly dedicated to God Almighty, the all- sufficient God and the master of the universe who granted me the grace to come this far.

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ABSTRACT

This research work evaluated some basic physical and chemical properties of Agricultural materials and its utilities in machine and structural design processes. Some physical and chemical properties of tiger nuts (yellow and Brown) were determined. For the physical properties and data include: shape (oblong cylindrical), size (12.28mm, 10.54mm, 7.94), surface area ($4.24 \times 10^{-5}m^2$), volume ($0.34cm^3$). Density ($1.82g/cm^3$) and moisture content (11.80%) for yellow dried nuts. Shape (oblong cylindrical), size (13.72mm, 12.21mm, 10.10mm), sphericity (1.11), weight ($8.83 \times 10^{-3}N$), Diameter 827mm) surface area (6.77 x 10-5m2), Volume (0.50cm3), Density ($1.80g/cm^{-3}$) and moisture content (95.30%) for yellow wetted nuts. Shape (oblong cylindrical), size (8.42mm, 7.04mm, 5.94mm), shericity (13.94), weight (1.96 x 10-3), Diameter (829mm), surface (1.03x10-5m2), Volume (0.30cm3), Density (0.67g/cm3) and moisture content (13.20%) for Brown dried nuts. For the chemical properties and data include: crude fibre content (6.50%), Lipid content (32.20), crude protein (7.15), Ash content (4.00%), Organic matter (96.00%) and percentage carbohydrate (56.65%) for yellow tiger nuts. Crude fibre content (5.50%) Lipid content (35.40%), crude protein (9.70%), Ash content (4.20%), Organic matter (95.80%) and percentage carbohydrate (50.70%) for Brown tiger nuts.

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CHAPTER ONE

1.0 INTRODUCTION

As a result of the ever-increasing world population to be fed and for raw-materials development, there is the need for the increase in production, handling, processing, preservation and marketing of plants and animals to meet up with food demand of the teaming population.

In developing countries like Nigeria, this has been made possible with by the application of modern technology which involves essentially the subjection of these materials to physical and mechanical treatment. For machines, processes and handling operations to be designed for maximum efficiency and highest quality of the end products of plant and animal materials, their physical properties are required. The increasing economics importance of food materials together with the complexity of modern technology for their production, handling, storing, processing, preservation, quality evaluation, distribution and marketing and utilization demand a better knowledge of the significant physical and chemical properties of these materials.

From the production units on the farm to the consumer, food materials are subjected to various methods involving mechanical treatment, thermal treatment, electrical treatment, optical treatment and some technique and devices. It is essential to understand the physical laws governing the response of these biological materials so that the machines, process and handling operations can be designed for maximum efficiency and the highest quality of the end products. The Tiger nut is not really a nut but a small tuber first discovered some 4000 years ago. It has many other names like Zulu nut, yellow nutgrass, almond, edible rush and rush nut.

1.1 Physical Properties

According to Mohsenin (1984), physical properties are parameters which are moisture contents dependent and are properties which are considered in the design and construction of equipment and machineries for the processing and handling of agricultural produce. These physical engineering properties will include:

- Shape
- Size
- Volume and density
- Weight
- Surface area
- Roundness ratio
- Moisture content
- Angle of repose
- Average mean diameter

1.2 Objective of the Study

The objective of this study is to determine some physical and chemical properties of Tiger nut that are considered important for its handling, storage and processing. These physical and chemical properties when determined can be used for the design of handling devices, storage structure and Tiger nut processing machine.

1.3 Justification of the Objective.

The study of some physical and chemical properties of Tiger nut has been an attempt to provide objective measurement resulting in a meaningful data in engineering analysis and design. The results obtained from most of these properties constitute important design parameters. The methods established in this study can also be used to determine the physical properties of other agricultural products similar in nature.

These data generated will make designers to conceptualize appropriate method of processing Tiger nut and as a result help in maximizing the productivity of tiger nut.

1.4 Scope of Study

The study of some physical and chemical properties of any material is so wide that it is difficult to completely be covered in a single project work of this nature. The non-available instrument to determine some of the properties makes it impossible to exhaust all the physical and chemical properties in this work.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Historical background of tiger nut

Zohary and Hopt (1980) consider this tuber "ranks among the oldest cultivated plants in **Ancient Egypt.**" Although noting that "chufa was no doubt an important food element in ancient Egypt during dynastic times, its cultivation in ancient times seems to have remained (totally or almost totally) an Egyptian specialty."

They were used to make cakes in ancient Egypt. Presently, they are cultivated mainly, at least far extended and common commercial purposes, in **Spain,** where they were introduced by **Arabs,** almost exclusively in the **Valencia** region. Tiger nuts are also grown in Ghana. The chufa, or Tiger nut, is often cultivated for its edible tuber in warm temperate and tropical zones, there is a cultivated variety cativus, that produces larger tubers.

Cyperus esculentus (chufa sedge, yellow Nusedge, Tiger nut sedge, Earthalmond) is a species of **sedge** native to warm temperate to subtropical regions of the **Northern Hemisphere**. It is an annual or perennial plant, growing to 90cm tall, with solitary stems growing from a tuber. The stems are triangular in section, and bear slender leaves 3-10cm wide. The flowers of the plant are distinctive, with a cluster of flat oval seeds surrounded by four hanging leaf-like **bracts** positioned 90 degrees from each other. The plant foliage is very tough and fibrous, and is often mistaken for a **grass**.

2.2 Description of tiger nut and the problem associated with the growth of the plant

Perennial sedge which produces small underground tubers in the fashion of wrinkled peanuts. The top of the plant is grass-like leaves up to 90cm (about 36 inches). Apparently the plant will produce a quite attractive yellow flower and assume a long, hot season is needed. Initially, the plan will produce leaf and flourish as plants do but as the days become shorter and cooler, leaf production will cease and tubers will be formed. The tubers are mainly bunched together directly beneath the plant with a few a little way away. Each tuber is attached to a thin rhizome (underground stem).

High temperatures and low nitrogen levels increase tuber production. Increased in day light (by lighting) will reduce tuber formation. The tuber epidermis (skin) contains substances which inhibit sprouting of tubers. This plant grows best in moist soil, tolerates high soil moisture and is intolerant of shade. We have had lots of problems with growing this cultivated form. Once the tubers come into growth then they normally grow vigorously, but the difficulty is getting them to come into growth. The tubers are harvested in the autumn and store them in moist sand, replanting them in the spring. However, they rarely come into new growth until mid to late summer which gives them too short a growing season to produce much of a crop. There is need to find a satisfactory way of storing the tubers and exciting them back into growth.

In warmer climates this plant is a serious weed of cultivation. It is much hardier than was once imagined and is becoming a weed in North America where it is found as far North as Alaska.The tubers are often formed a metre or more away from the plant, especially if it is growing in a heavy clay soil. The tubers are extremely attractive to mice and require protection from them in the winter.In Spain it is very popular and is known as

CHUFA. It is one of two major species of the nutsedge gerus Cyperus found as a weed in the tropics and subtropics on all types of disturbed soil. Its close relative *Cyperus rotundus* (Purple nutgrass) is a severe problem weed in Florida (U.S.A).

The scientific name is *Cyperus esculentus*. The genus name Cyperus is from Cypeirus, the ancient Greek name for this gerus. The species name esculentus is Latin and means edible. Tiger nuts have been cultivated both as a livestock food and for human consumption of the tubers, eaten raw or baked. The tubers are about the size of peanuts and are abundantly produced. Eaten raw they make a very acceptable snack and have a flavour and texture reminiscent of coconut. They can be rehydrated by soaking before consumption and even softened further by boiling. Tiger nuts are rich in oil which can be extracted for culinary and industrial use. "Horchata" is vegetable milk made with Tiger nut juice which is very popular in Spain.

2.3 **Popularity in cultivation and propagation**

Tiger nuts were widely grown in Florida in the 1940's, in the 1980s, they were still grown for livestock feed on a few farms. In Spain, Chufa is planted outdoors from late spring to midsummer by dropping the dried tubers 15 to 30cm apart in rows 60 to 90cm apart. Tiger nuts are widely cultivated in and exported from china, Mali and Ivory Coast. Seldom grown as a food item in home gardens, these nuts were widely available in Britain in the 1960's although they are rare and exotic nowadays. Apparently they gained popularity in the post-war years when sugar was in short supply but subsequently fell out of favour and are now only available in health food shops or as fishing bait.

Seed-surface sows in the spring and keep the compost moist. The seeds usually germinate in 2-6 weeks at 18^0C. Prick out the seedlings into individual pots as soon as they are large enough to handle. Grow on for their first winter in a green house and plant them out in late spring after the last expected frosts.

2.4 Physical properties

Information on physical properties are among the fundamental bedrock unto innovation. As a matter of fact, it will undoubtedly enhance techno-scientific development with respect to food production. To increase the production of Tiger nuts together with the complexity of modern technology of its production, it physical and chemical properties must be carefully studied and understood as they play vital role in the design of machine structures, processes and control, (Mohsenin, 1984).

2.4 Removal and physical characteristics of tiger nuts

It is extremely difficult to remove permanently when it is considered to be an intrusive **weed** in **lawns** and **gardens**. This is due to the plant having a stratified and layered root system, with tubers and roots being interconnected to each other to a depth of 50cm or more. The tubers are connected by fragile roots that are extremely prone to snapping when pulled on, making the plant extremely difficult to remove with its entire root system infact, and the plant can quickly regenerate if even a single tuber is left in place. Repeated application Gordon's Trimecphis have proven effective in eliminating this weed from lawns. The flowers are hermaphrodile (have both male and female organs) and are pollinated by wind.The plant prefers light (sandy), medium (loamy) and heavy (clay) soils and can grow in heavy clay soil. The plant prefers acid, neutral and basic (alkaline) soils. It cannot grow in the shade. Its habitants and possible locations are **Bog Gardens** and **Cultivated Beds**.

2.6 Nutritional benefits of tiger nuts.

Tiger nuts have long been recognized for their health benefits as they are high in fibre, proteins, and natural sugars. They have a high content of soluble glucose and oleic acid. Along with a high energy content (starch, fats, sugars and proteins), they are rich in minerals such as phosphorus and potassium and in vitamins C and E. It is believed that they help to prevent heart attacks, thrombosis cancer especially of colon. They are thought to be beneficial to diabetics and those seeking to reduce cholesterol or lose weight. The very high fibre content combined with a delicious taste, make them ideal for healthy eating.

Typically 100g Tiger nuts contains 386kcal (1635KJ) as 7% proteins, 26% fats (oils), 31% starch, 21% glucose. They contain 26% fibre of which 14% is non-soluble and 12% soluble.

2.6.1 Mineral content of tiger nuts in mg

The mineral content of tiger nuts are displayed in the table below.

Table 1: the table showing various mineral content of Tiger Nuts

SERIAL NUMBER	ELEMENT	MINERAL CONTENT (Mg)
1.	Sodium (Na)	34
2.	Calcium (Ca)	92
3.	Iron (Fe)	4
4.	Zinc (Zn)	3.5
5.	Phosphorus (P)	211
6.	Potassium (K)	424
7.	Magnesium (Mg)	93
8.	Copper (Cu)	0.97
9.	Manganese (Mn)	0.25

Source: Cantalejo MJ (1997)

2.6.2 Uses and consumption of tiger nuts

Tiger nuts are generally dried out to preserve them. This can take three months and they need turning over occasionally to ensure uniform drying. This can be kept for several years and can be reconstituted by soaking overnight. They can be further softened by boiling but it was found that as with coconut and pineapple, no amount of cooking will render them truly soft.If they are still too chewy for one's taste, putting them through a food grinder, the result can be incorporated easily in many recipes in place of or together with coconuts.

2.6.3 Uses of tiger nuts

Tiger nuts have many users.

Use as food

The **tubers** are **edible**, with a slightly sweet, nutty flavour, compared to the more bitter tuber of the related *Cyperus rotundus* (Purple Nutsedge). They are quite hard and are generally soaked in water before they can be eaten. They have various uses; in particular, they are used in Spain to make "horchata." They are sometimes known by their **Spanish** name, "Chufa." Tiger nuts are also **gluten** and **cholesterol** free, and have a very how **sodium** content. The oil of the tuber was found to contain 18% saturated (**Palmitic acid** and **Stearic acid**) and 82% unsaturated (**Oleic acid** and **Inoleic acid**) **fatty acids**. According to the Regulating Council for Valencia's tiger nuts, the nutritional composition per 100ml of a classical **Horchata chufa** is as follows: The energy content is around 66kcal but other nutritional composition of Tiger nuts are given in the table below.

Table 2: The table showing the nutritional Composition of Tiger nuts.

FOOD	COMPOSITION (g)
Proteins	0.5
Carbohydrates	Over 10
Starch	Greater than or equal to 1.9
Fats	Greater than or equal to 2

Source: Chittendon, 1992.

It can replace milk in the diet of people intolerant to **Lactose**.

Edible uses of tiger nuts

Tuber – raw, cooked or dried and grind into a powder. They are also used in confectionery. A delicious nut like flavour but rather chewy and with a tough skin. They taste best when dried. They can be cooked in barley water to give them a sweet flavour and then be used as a desert nut. A refreshing beverage is made by mixing the ground tubers with water, cinnamon, sugar, vanilla and ice. The ground up tuber can also be made into a plant milk with water, wheat and sugar.

An edible oil is obtain from the tuber. It is considered to be a superior oil that competes favourably with olive oil. The roasted tubers are a coffee substitute (Hedrick, 1979)

Tiger nut milk, the healthiest soft drink

Typical drink of the Spanish east, the tiger nut was known till now for its great fresh power in the summer months. But its properties go much further than theat. An elaborated studies in the politecnico in Valencia university reveals a lot of goodnesses for the health, emphasizing the reduction of "bad" cholesterol.

The study managed for the Doctor Enrique Hernandez, Professor of microbiology from this Valencia university emphasizes the curative and antioxidant properties of the tiger nut milk, which its high content in vitamin E diminishes the cholesterol, harmful for the health. The secret of its healthy success is in the high percentage of **Oleic acid** which has "rather more that the olive oil."

But there is even more, according to this studio, for its nutritional values, even higher that the chocolate, is ideal for children, old and sporty people. Also for the presence of sucrose, it is specially recommendable for diabetics.

The tiger nut milk is a drink produced from the tiger nut (Cyperus esculentus), a dry and brown fruit, with creases in the surface which is cultivated 7 or 8 months (that is it is sowed in April and picked in November).

Its origin is Egypt, and its cultivation was introduced in our country by the Arabic people, specially in the East coast, as a product of delicate smell and taste, and as a base of the drink obtained from its maceration. Nowadays, the only area of Europe where it is grown is L' Horta Nord in Valencia (just in 16 towns), where the lands have an ideal weather and ground conditions for that singular tuber.

Tiger nuts, sugar, water and a bit of cinnamon or lemon peel are the basic ingredients of this fresh drink with wonderful power.

The nutrient more abundant in its composition are the carbohydrates, are also found proteins, vitamins E and C, minerals like magnesium, iron ore and calcium, and in small amounts fats, mainly no saturated. The tiger nut milk also contains enzymes, substances which make the digestion easien and hasn't got cholesterol. It is showed as one of the healthiest options to refresh one self in summer.The energy content of tiger nut milk is about 69.75kcal. The other composition of the tiger nut milk are as follows:

Table 3: The table showing the nutritive composition of the tiger nut milk (each 100ml) by Fernando Belda.

Proteins	0.60 (g)
Fats	2.40 (g)
Carbohydrates	12.20 (g)
Calcium	11.30 (Mg)
Iron Ore	0.46 (Mg)
Cholesterol	0.0 (Mg) negligible.

Other uses of tiger nuts

The tubers contain up to 30% of a non-drying oil, it is used in cooking and in making soap. It does not solidify at 0^0C. and stores well without going rancid.The leaves can be used for waving hats and matting.

2.7 Description of the physical properties

2.7.1 Shape and size:

These are properties by which Agricultural materials can be described. They are required in the determination of the number of materials to fill a container. These properties are used for the design of hoppers and grinding and separating equipment such as graters, sieve and screen (Mohserin, 1984).

2.7.2 Volume and density:

These are important parameters in the drying equipment, storage structures such as silos, separation equipment such as Pneumatic and electronic devices (Mohserin, 1984).

2.7.3 Surface area:

Knowledge of surface area is very important in handling and processing of agricultural materials e.g. the more the surface area of a materials, the easier it is to cool, dry, mix with other constituent (Mohsenin, 1984).

2.7.4 Roundness:

Roundness is a measure of the sharpness of the corners of the solid. It can be estimated using several methods. It is a parameter of considerations in designing.

2.7.5 Sphericity:

The geometric foundation of the concept of sphericity rest upon the rest upon the Iso-perimetric property of a sphere. Different agricultural products have different sphericity. This bases is applicable in designing. (Mohsenin, 1984).

2.7.6 Moisture content:

This is the measurement of amount of water content in a produce. Biological activities occur when moisture is present (Hayme, 1990). So, there is the need to reduce moisture content of products to be stored for safe storage. There is an equilibrium state between moisture present in produce and the water vapour around it.

Moisture content of a produce according to Hayme, 1990 therefore can be defined as a numerical value expressed in percentage which is determined in a given sample of nut and the weight of that sample. The determination of the moisture content parameters, help us to know the state of the materials at the time of the experiment.

2.7.7 Angle of repose:

The angle of response is the angle with the horizontal at which the materials will stand when piled (Mohsenin, 1984). The physical properties of these materials such as shape and size, colour, moisture content and the orientation of the materials have a decided influence on the angle of repose. Although, some engineers referred to angle of repose as the angle of internal friction, but Stewart (1964) has shown that for granular material that he tested (Sorghum grain) the two angles are different and the use of one in place of the other may introduce an error in design. Angle of repose are of two types, namely;

2.7.7.1 Static angle of repose:

This is the angle of friction taken up by a granular solid about to slide upon it self.

2.7.7.2 Dynamic angle of repose:

This is related to a situation where a bulk of the materials is in motion such as the movement of solid discharge from a bin and hopper. It is more important than the static angle of repose.

2.8 Chemical properties

2.8.1 Proximate (basic) composition of tiger nut

A team of scientists under the leadership of Henneberg and Stohmann developed proximate principles analysis system in the sixties of last century at Weende Experimental station. Main components of different fractions in the proximate analysis of foods are moisture, ash, crude protein, ether extract, crude fibres, and nitrogen free-extract.

These workers emphasized that carbohydrates could be grouped into:

1. The starches and the sugars and
2. A coarse fibrous fraction. Later on an insoluble residue after boiling the fat free food sample first with dilute acid stomach digestion and the subsequent alkaline instestional digestion of consumed food. At the end of digestion insoluble organic residue was denoted as Crude fibre.

In Weende's system of analysis "soluble carbohydrate" was called Nitrogen – free – extract (NFE).The areas of interest in the proximate composition include; protein content, carbohydrate, crude fat, crude fibre and ash content as the moisture content has been determined in the physical properties.

2.8.2 Crude protein

According to Weende's food analysis scheme, nitrogenous fraction of food may be divided into two portions – protein and non-protein. Protein is made up of dispensable amino acids- glutamic acid, aspartic acid, alarine, serine, praline,hydroxyl praline, semidispensible amino acids-arginino, glycine, histidine, cystine, typrosine; indispensable amino acids-lysine, trytophan, leucine, phenylalanine, methionine, threonine, isoleucine, valine. Another part of non-protein nitrogen consist of urea nitrogen, ammonia nitrogen, uric acid nitrogen consist of urea nitrogen, ammonia nitrogen, uric acid nitrogen, free amino acids, amines etc. overall protein may be divided into two portions-True protein and non-protein nitrogen.

True protein nitrogen is estimated by stutzer reagent method, (where protein is precipated with cupric hydroxide in alkaline conditions) while non-protein nitrogen fractions e.g. urea nitrogen, ammonia nitrogen are estimated accurately by Conway diffusion technique.

2.8.3 Carbohydrate

Carbohydrate portion of biological material is made up of two parts- nitrogen – free – extract and crude fibre. Nitrogen – free – extract is also known as soluble carbohydrate which consists of water soluble vitamins, Monosaccharides (simple pentose or hexose sugars) Oligosaccharides (compound sugars), Polysaccharides (starches).

Insoluble carbohydrate (Crude fibre is mainly polysaccharides consisting of hemicellulose and cellulose. Actually, residue of a feed that, is insoluble after successive boiling with dilute alkali and dilute acid is known as a crude fibre and contains beside cellulose a part of nitrogen also. It has been experienced that Weende crude fibre may be a misleading index of the overall digestibility of a feed, because crude fibre itself is atleast as highly digested as the soluble carbohydrate (nitrogen-free-extract).

Crude fibre gives an indication of bulkiness of a feed. As per Weende's method, some of lignin, pentosans and part of the cellulose are dissolved and included in calculation of NFE.

2.8.4 Crude Fat (Lipid Content)

Crude fat is also known as ether extract. This is a combination of simple fat-fatty acid esters, compound fat, neutral fat, neutral fat, sterolspseudo fat (vitamins A, D_2, D_3, E, K) and Carotene. Fat is estimated by extraction with petroleum ether (boiling point 40^0-60^0C) by extraction with ether in a Soxhlet extractor. Too high values may be encountered with silages, and sometimes oil cakes due to oxidized fat or calcium soaps in faeces which are not completely extracted. Treatment with acid ahead of the extraction of faeces, and when the foods stuffs are extracted with a better solvent (chloroform-methanol, benzene-methanol, ether-methanol, acetone or isopropy/alcohol), it gives better results. Part of the fat or calcium soaps in faeces which are not completely extracted.

The faeces of animals sometimes contain fatty acids bound to calcium and may escape the assay in this way. A series of analyses conducted in the department of Animal Nutrition/Agricultural University of Norway), revealed that the yield of extractable fat is increased by pretreatments with hydrochloric acid (HCl). Generally gross energy of crude fat is 9.40Kcal per gram of feed.

Generally, two methods of extracting the fat from biological samples are followed. In the first method weight of extracted material is recorded after evaporating the solvent and loss in weight of the moisture – free sample following its extraction is known as crude fat. In the second method difference in the weight of oil flask is recorded which is denoted as crude fat. Second method gives accurate results.

2.8.5 Ash Content

The ash of a biological material is analytical term for the inorganic residue, that remains after the organic matter has been burnt way in the furnace usually at a temperature of 550^0C. The ash is not usually the same as the inorganic matter present in the original food since there may be losses due to the volatilization or chemical interaction between the constituents. The value is useful in assessing the quantity or grading certain edible materials.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The materials and test procedures used for the determination of the under-listed properties are as follows (almost all the experiments were conducted using five selected samples for dry and wet Tiger nuts (plates 1 and 2 respectively) and the values obtained were established in details in the discussion of results.

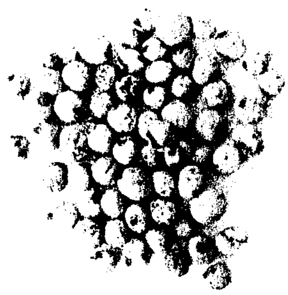

Plate 1: Yellow wet samples

Plate 2: Dry Samples

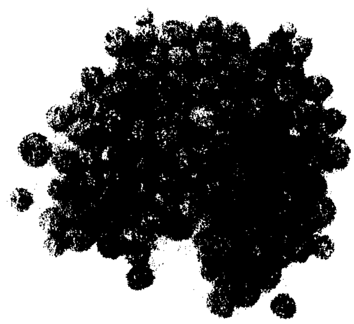

Plate 3 Dry Samples of Brown Tiger Nuts

Shape and size

Shape and size are generally required for satisfactory description of the agricultural materials. There are various methods of determining shape and size of agricultural materials outlined by Mohsenin (1984). Some of them include:

4.0 Use of chartered standards

5.0 Use of resemblance to geometric shapes

6.0 Use of overhead projector/shadow graph

7.0 Measurement of dimensions on three mutually perpendicular axes.

The last method appears to be most widely used. Determination of the principal dimension (major, intermediate and minor diameters) on three mutually perpendicular axes using pair of venier calipers.

Shape: To determine the shape of Tiger nut, tracing of the longitudinal and lateral cross section of the tiger nuts dried and wetted were done. This was compared with the shape listed on a chartered standard (Mohsenin, 1970).

Using the standard charts descriptive terms were used to define the shape of the product (Tiger nuts) over five replicates.

Size: To determine the size of the Tiger nut diameter ascending to Mohsenin, the mutually perpendicular axes a, b and c referred to major, intermediate and minor diameters were measured using a pair of caliper with a least count of 0.01mm, a specified number of samples (Five samples) for both dried and wetted were randomly picked and numbered.

Measurement of dimension on three mutually perpendicular axes viz major, intermediate and minor diameters were performed using a pair of caliper with the least count of

0.01mm. The mean values of the fire samples were now determined in order to obtain the average of the three axes i.e. (The major, intermediate and minor diameter). The procedures were done or repeated for both dried and wetted nuts.

3.1.1 Weight

The mass of each nut was obtained using electronic weighing balance with a least count of 0.1g. Results were obtained for fire replicates and the average recorded.

The weight was then calculated using the relationship

Weight (W) = Mass x Acceleration due to gravity

$$W = M \times g$$

$$W = Mg$$

Where

M = Mass of the nut

g = Acceleration due to gravity = 9.18m/s^2

3.1.2 **Sphericity**

According to Mohsenin (1984), the geometric foundation of the concept of sphericity rest upon the isopemetric property of a sphere. The mean values obtained for the major, intermediate and minor diameters from the five selected samples were used in determining the sphericity for both dried and wetted nuts. The values were substituted into the formula below

$$\text{Sphericity, } S = \frac{[abc]^{1/3}}{a} = \frac{\text{Geometric Mean Diameter}}{\text{Major Diameter}}$$

Where;

a = Major diameter of the Tiger nut

b = Intermediate diameter of the Tiger nut

c = Minor diameter of the Tiger nut

3.1.3 Surface Area

Methods for determination of surface area of agricultural materials such as leaf, fruits, and egg as listed by Mohsenin (1984) include;

1.Peeling the fruit in narrow strip and the planimeter sum of the areas of traced of the strips gives the surface area.

2.The use of shado graph.

3.Covering the surface of the material (e.g. egg) with strips of narrow masking tape and the areas of this tape traced.

4. Measurement taken on the principal dimensions of the material (e.g. fruits) using a pair of calipers and these dimensions used for the assumed geometric shape to calculate the surface area.

5.Coating the surface of the samples with paint and contact print on a flexible paper and edges traced. The planimeter sum of the traced gives the surface area.

Mittal J.P. (Design Related Physical Properties of selected Agricultural products, 1983) calculated the surface area of selected agricultural product using this formula.

$$S.A = 0.025W^{1.25}$$

Where;

S.A = Surface area of the agricultural material

W = Weight of the agricultural material

The weights of Tiger nuts (dried and wetted) were obtained using the electronic weighing balance and the mean values of the weights were substituted into the state formula ($S.A = 0.025W^{1.25}$).

3.1.3 Average geometric mean diameter (AGMD)

Gupta and Das (1997), Olajide and Ade-Omowaye (1999) and Jan and Bal (1997) calculated the Average Geometric Mean Diameter of sun flower seeds, locust bean seeds and pearl millet by the following formulae respectively;

$$De = (LBT)^{1/3}$$

$$Dp = (LWT)^{1/3}$$

$$D = (D_2D_3)^{1/3}$$

Alabadan, (1990) calculated the geometric mean diameter of cowpea using this empirical formula (physical properties of selected Biomaterials as related to their Post Harvest Handling 1999).

$$D = 0.83e^{-0.38W}$$

Where;

D = Average geometric mean diameter

W = Weight of the Agricultural materials

The weights of Tiger nut (dried and wetted) were obtained using the electronic weighing Balance and the mean values of the weight were substituted into the state formula ($D = 0.83\ e^{-0.38W}$).

3.1.4 Roundness ratio

According to Mohsenin (1984), the roundness of any agricultural product can be estimated or calculated thus:

$$\text{Roundness} = \frac{AP}{AC}$$

Where;

AP = Largest projected area of object in natural rest position.

AC = Area of smallest circumscribing circle.

The tiger nut areas were obtained by tracing.

The largest projected areas of the tiger nuts (dried and wetted) in natural rest position and their small areas of circumscribing circle were determined over the five selected replicates. The roundness ratios were obtained accordingly.

3.1.5 Volume and Density

Volume and Density play important roles in many applications as earlier mentioned in Chapter two.

Methods for determination of volume and density as listed by Mohsenin (1984) include;

3. The use of plat form scale
4. Air compression Pychometer for solid particles
5. Resemblance to a geometric shape e.g. fresh egg is assumed to be prolate spheroid shape hence volume is calculated from the expression

$$V = 4/3\pi\,(ab^2)$$

- Water displacement method for non-water objects

The volumes of the tiger nuts were determined using the last method. That is water displacement method. A small metal bob (Pendulum bob) was used as a sinker.

Water was poured into a 1000cm3 capacity measuring cylinder and the level noted. The bob was immersed in water noting the final level to which the water rise. The difference between the final and the initial water levels give the volume of the bob.

The nuts were then tied with a light inextensible string to the sinker and both immersed in water. The difference between the final and initial water levels for both the nuts and the bob was obtained. The volume of the nut was calculated by subtracting the volume of the bob from this difference.

The procedure was followed for all the wetted and dried nuts. The mass of each nut was obtained using electronic weighing balance with a least count of 0.1g. The density was calculated using the relationship

$$\text{Density } (\rho) = \frac{\text{Mass}}{\text{Volume}}$$

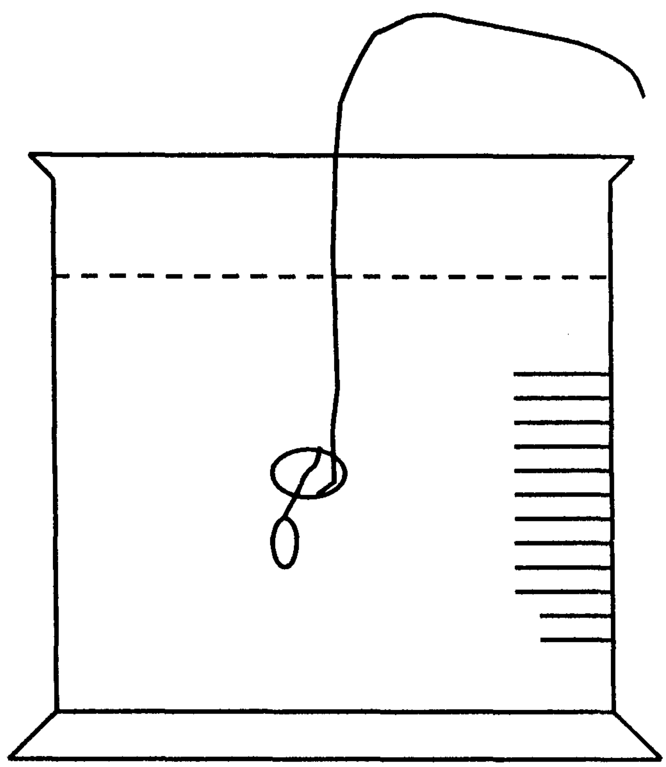

Fig 1: Volume determination using Water Displacement method.

3.2 Materials and methods for chemical properties

The two varieties of tiger nut used (yellow and brown) were obtained from Gwari market in Minna, Niger State, Nigeria. The nuts were cleaned, soaked, washed, drained, dried in an oven and ground into flour. The flour samples were passed through a 45μm mesh size sieve. The yellow and brown tiger nut flours were tagged YTF and BTF, respectively.

Material: *Cyperus esculentus*

Reagents and instrumentsare listed below:

Reagents

Tetraoxosulphate (vi) acid, (H_2S0_4), Sodium hydroxide (NAOH), Calcium chloride ($CaCl_2$), Calcium hydroxide [$Ca(OH)_2$], Methyl orange indicator, Ammonium chloride (NH_4Cl), Petroleum ether.

Crucibles, Furnance, Petri dishes, Desiccators, Filter paper, Water bath, Oven, Soxhlet extractor, Flat bottom silica dishes, Bursen burner, Beakers, Pipette, Thimbles Conical flask, muffle furnace.

3.1.6 Determination of crude fibre

The crude fibre of the samples was determined using AOAC (1980) guidelines.

3.1.6.1 Procedure:

Two conical flasks, were weighed (W_1), 2g of each of the samples were put in the conical flasks and weighed (W_2). H_2SO_1 and NaOH were then put in an oven at 50^0C for 6 hours.

They were removed from the oven, cooled in desiccators and weighed (W_3). Crude fibre is the loss in weight during incineration.

$$\text{Crude fibre content (\%)} = \frac{W_2 - W_3}{W_2 - W_1} \times 100$$

3.1.7 Determination of lipid content

The lipid content of biological materials can be estimated by direct extracting the dry materials exhaustively using suitable lipid content like Petroleum ether at 40 – 60^{0}C. Lipid in a convenient continuous extractor, such as soxhlet, Bottom type. Direct extraction gives a portion of free fat.

3.1.7.1 Procedure:

Two containers (thimbles were cleaned and weighed (W_1), 5g of the samples was taken into a thimble (container) and weighed, (W_2). Petroleum ether was added to the thimbles with samples. The thimbles or containers with sample were placed inside a Soxhlet extractor. The Soxhlet extractor with the thimble plus sample is filled into the flask, which is sitted in Bunsen burner. Heat was increased carefully and slowly until the solvent boils.

(condensed solvent vapour were collected in the thimble and dissolve the lipid in the sample. The solvent with dissolved lipid continuously ran back into in the flask). The process was continued for 6 hours when the thimble with contents were removed, dried in an oven at 50^{0}C for 8hours, cooled in a desiccator and reweighed (W_3).

$$\text{Lipid (\%)} = \frac{W_1 - W_3}{W_2 - W_1} \times 100$$

3.1.9 Determination of ash content

3.1.9.1 Principle

The residue of ash consists of the inorganic component in the form of their oxides.

3.1.9.2 Procedure:

The crucibles used were cleaned, dried, cooled in a desiccator and weighed (W_1), 5g of the tiger nut flour samples for both the yellow and brown was put in the crucibles and weighed (W_2). The samples and the crucibles were heated on a hot Bunsen burner in a fume cupboard until smoking ceased, or until no more soot was given off. It was then transferred to a muffle furnace heated to about 500^0C. This heating continued for 24 hours before all the carbon were burnt off. The furnance was then switched off and the crucibles were taken out, covered immediately and placed inside a desiccator and weighed (W_3)

$$\% \text{ Ash content} = \frac{W_3 - W_1}{W_2 - W_1} \times \frac{100}{1}$$

3.1.10 Determination of Carbohydrate Content

This is the subtraction of the total protein and lipid contents from the organic matter.

That is,

% Carbohydrate = % Organic matter – (% protein + % lipid contents)

But % Organic matter = $\frac{W_3 - W_1}{W_2 - W_1} \times \frac{100}{1}$ in 3.2.4 above.

CHAPTER FOUR

RESULTS AND DISCUSSION

Results

4.1.0 Shape and Size

Shape: The shape of tiger nut when compared with that of Mohserin (1984) standard is oblong cylindrical.

Size

Table (4): principal dimensions determination for yellow dried nuts

For Yellow Dried Nuts

Samples	Major (mm)	Intermediate (mm)	Minor (mm)
1.	13.70	10.98	8.90
2.	13.50	10.20	9.20
3.	12.00	11.40	7.30
4.	10.70	9.42	7.30
5.	11.52	10.70	7.00

3.1.8 Determination of crude protein

Preparation of reagent; was dissolved 0.4g of NaOH in 50ml of distilled water and shaken properly to give 0.2M solution of NaOH.

3.1.8.1 Procedure:

1g of Tiger nut flours (both yellow and brown) samples was taken, 5mls of NaOH solution and 0.5M H2SO4 were added to the samples. The samples and the reagents were mixed thoroughly and allow settle for 15 minutes. This was then filtered using filter paper. 5ml of filtrate was put into clean conical flask, and 5ml of distilled water was added. 2 drops of methyl orange indicator was added and shaken. This was titrated against 0.5M. H_2SO_4. The titres values for yellow and brown Tiger nut are 17cm3 and 20cm3 respectively.

Equation of reactions:

$$2NaOH + H_2SO_4 \longrightarrow (Na)_2SO_4 + 2H_2O$$

$$\text{Nitrogen (\%)in the sample} + \frac{\text{correct titre(ml)} \times 14 \times 5 \times 100}{1000 \times 70 \times \text{weight of sample(g)}}$$

Crude protein content (%) = 6.25 x Nitrogen (%)

Table (5): Principal dimensions determination for yellow wetted nuts

For Yellow Wet Nuts

Samples	Major (mm)	Intermediate (mm)	Minor (mm)
1.	15.30	14.00	9.70
2.	14.60	12.10	10.60
3.	12.30	10.54	10.00
4.	13.80	12.42	11.00
5.	12.60	12.00	9.22

Table (6): Principal dimensions determination for Brown Dried nuts

For Brown Dry Nuts

Samples	Major (mm)	Intermediate (mm)	Minor (mm)
1.	9.10	7.26	6.00
2.	9.20	7.22	6.60
3.	8.00	6.30	4.80
4.	8.00	7.00	6.30
5.	7.80	7.40	6.00

For yellow Dried Nuts

$$\text{Mean major diameter} = \frac{13.70 + 13.50 + 12.00 + 10.70 + 11.52}{5}$$

$$= \frac{61.42}{5} \quad = \mathbf{12.28mm}$$

$$\text{Mean intermediate diameter} = \frac{10.98 + 10.20 + 11.40 + 9.42 + 10.70}{5}$$

$$= \frac{52.70}{5} = \mathbf{10.54mm}$$

$$\text{Mean minor diameter} = \frac{8.90 + 9.20 + 11.20 + 11.40 + 9.42 + 10.70}{5}$$

$$= \frac{52.70}{5} = 10.54mm$$

$$\text{Mean minor diameter} = \frac{8.90 + 9.20 + 7.30 + 7.30 + 7.00}{5}$$

$$= \frac{39.70}{5} = 7.94mm$$

For yellow wetted Nuts

$$\text{Mean major diameter} = \frac{15.30 + 14.60 + 12.30 + 13.80 + 12.60}{5}$$

$$= \frac{68.60}{5} = \mathbf{13.72mm}$$

$$\text{Mean intermediate diameter} = \frac{14.00 + 12.10 + 10.54 + 12.42 + 12.00}{5}$$

$$= \frac{61.06}{5} = \mathbf{12.21mm}$$

$$\text{Mean minor diameter} = \frac{9.70 + 10.60 + 10.00 + 11.00 + 9.22}{5}$$

$$= \frac{50.52}{5} = \mathbf{10.10mm}$$

For Brown dried Nuts mean major diameter = $\frac{9.10 + 9.20 + 8.00 + 7.80}{5}$

$= \frac{42.10}{5}$ = **8.42mm**

Mean intermediate diameter = $\frac{7.26 + 7.22 + 6.30 + 7.00 + 7.40}{5}$

$= \frac{35.18}{5}$ = **7.04mm**

Mean minor diameter = $\frac{6.00 + 6.60 + 4.80 + 6.30 + 6.00}{5}$

$= \frac{29.70}{5}$ = **5.94mm**

4.1.1 Weight

Weight = mg

For yellow Dried Nuts,

$M = 0.62g = 6.2 \times 10^{-4}kg$, $g = 9.81 m/s^2$

$\therefore W = 6.2 \times 10^{-4} \times 9.81$

$= 6.08 \times 10^{-3} N$

For yellow wetted nuts,

$M = 0.90g$, $= 9.0 \times 10^{-4}kg$, $g = 9.81 m/s^2$

$\therefore W = 9.0 \times 10^{-4} \times 9.81$

$= 8.83 \times 10^{-3} N$

For Brown Dried Nut,

$M = 0.20g = 2.0\times10^{-4}kg, g = 9.81m/s^2$

$\therefore W = 2.0\times10^{-4} \times 9.81$

$= 1.96 \times 10^{-3}N$

4.1.2 Sphericity

$$S = \frac{[abc]^{1/3}}{a}$$

For yellow Dried Nut

$$S = \frac{[12.28 \times 10.54 \times 7.94]^{1/3}}{12.28}$$

$$= \frac{342.56}{12.28}$$

$$= \mathbf{27.90}$$

For yellow wetted Nut,

$$S = \frac{(13.72 \times 12.21 \times 10.10)^{1/3}}{13.72}$$

$$= \frac{563.99}{13.72}$$

$$= \mathbf{41.11}$$

For Brown Dried Nuts

$$S = \frac{(8.42 \times 7.04 \times 5.94)^{1/3}}{8.42}$$

$$= \frac{117.37}{8.42}$$

= **13.94**

4.1.3 Surface Area

$S.A = 0.025W^{1.25}$

For yellow Dried Nut, $W = 6.08 \times 10^{-3}N$

$S.A = 0.025\,(6.08 \times 10^{-3})^{1.25}$

$S.A = 4.24 \times 10^{-5} m^2$

For yellow wetted nut $W = 8.83 \times 10^{-3}N$

$S.A = 0.025\,(8.83 \times 10^{-3})^{1.25}$

$S.A = 6.77 \times 10^{-5} m^2$

For Brown dried Nut, $W = 1.96 \times 10^{-3}N$

$S.A = 0.025\,(1.96 \times 10^{-3})^{1.25}$

$S.A = 1.03 \times 10^{-5} m^2$

4.1.4 Average Geometric Mean Diameter

$D = 0.83e^{-0.38}W.$

For yellow Dried Nut, $W = 6.08 \times 10^{-3}N$

$D = 0.83e^{-0.38} \times 6.08 \times 10^{-3}$

D = 0.828m = 828mm

For yellow wetted Nut, $W = 8.83 \times 10^{-3}N$

$D = 0.83e^{-0.38} \times 8.83 \times 10^{-3}$

D = 0.827m = **827mm**

For Brown Dried Nut, $W = 1.96 \times 10^{-3}N$

$D = 0.83e^{-0.38} \times 1.96 \times 10^{-3}$

D = 0.829m = **829mm**

4.1.5 Volume

Dried yellow Nut

Initial volume of water = 145cm^3

Final volume of water = 146.7cm^3

Volume of the dried (yellow) tiger nuts

= (146.7 – 145) cm^3 = 1.7cm^3

Mean value = $\frac{1.7cm^3}{5}$ = 0.34cm^3

Wetted yellow Nuts

Initial volume of water = 145cm^3

Final volume of water = 147.5cm^3

Volume of the wetted (yellow) tiger nuts

= (147.5 – 145) cm^3 = 2.5cm^3

Mean value = $\frac{2.5}{5}$ = 0.5cm^3

Dried Brown Nuts

Initial volume of water = 145cm^3

Final volume of water = 146.5cm^3

Volume of the dried (brown) tiger nuts

= (146.5 – 145) cm^3 =1.5cm^3

Mean value = $\frac{1.5}{5}$ = 0.30cm^3

4.1.6 Density

$$\text{Density}, P = \frac{\text{Mass}}{\text{Volume}}$$

For yellow dried Nut

Mass = 0.62g, Volume = 0.34cm^3

$$\text{Density} = \frac{0.62}{0.34} = 1.82\text{g/cm}^3$$

For yellow wetted Nut,

Mass = 0.90g, Volume = 0.50cm^3

$$\text{Density} = \frac{0.90}{0.50} = 1.80\text{g/cm}^3$$

For Brown dried Nut,

Mass = 0.20g, Volume = 0.30cm^3

$$\text{Density} = \frac{0.20}{0.30}$$

$$= \mathbf{0.67g/cm^3}$$

Table (7): Moisture Content determination on dry basis

4.1.7 Moisture Content

A		B		C	
Yellow Dried Tiger Nut		**Yellow wet tiger Nut**		**Brown Dry Tiger Nut**	
Initial Can	Can+Tiger Nut	Can	Can + Nut	Can	Can + Nut
		14.96_{w1}	58.54_{w2}	14.98_{w1}	51.72_{w2}
$Wt(g)_{w1}$ 14.48	53.89_{w2}				
Final		14.96	37.27_{w3}	14.98	47.45_{w3}
wt(g) 14.48	49.73_{w3}				

$$\text{Moisture content (dry Basis)} = \frac{(W_2 - W_1) - (W_3 - W_1)}{W_3 - W_1}$$

For A

$$\text{Moisture content} = \frac{(53.89 - 14.48) - (49.73 - 1448)}{49.73 - 14.48} \times \frac{100}{1}$$

$$= \frac{39.41 - 35.25}{35.25} \times \frac{100}{1}$$

$$= \frac{4.16}{35.25} \times \frac{100}{1}$$

A = **11.8% (D.B)**

For B

$$\text{Moisture content} = \frac{(58.54 - 14.96) - (37.27 - 14.96)}{37.27 - 14.96} \times \frac{100}{1}$$

$= \frac{21.27}{22.31} \times \frac{100}{1}$

$= \mathbf{95.3\%\ (D.B)}$

For C

Moisture content $= \frac{(51.72 - 14.98) - (47.45 - 14.98)}{47.45 - 14.98} \times \frac{100}{1}$

$= \frac{36.74 - 32.47}{32.47} \times \frac{100}{1}$

$= \frac{4.27}{32.47} \times \frac{100}{1}$

Moisture content = **13.2% (D.B)**

Results of Proximate Analysis for Tiger Nut

4.2.1 Guide Fibre Content (%)

$W_1 = 126.51g$

$W_2 = 128.51g$ for yellow

$W_3 = 128.38g$

Guide Fibre Content %=

$\frac{(128.51 - 128.38)}{128.51 - 126.51} \times \frac{100}{1}$

$= \frac{0.13}{2} \times \frac{100}{1}$

= 6.50% yellow

For Brown

$W_1 = 98.51g$

$W_2 = 100.51g$

$W_3 = 100.40g$

Guide Fibre Content %=

$\frac{(100.51 - 100.40)}{100.51 - 98.51} \times \frac{100}{1}$

$= \frac{0.11}{2} \times \frac{100}{1}$

= 5.50% yellow

4.2.2 Lipid Content (%)

For yellow

$W_1 = 3.85g$

$W_2 = 8.85g$

$W_3 = 2.24g$

Lipid Content %=

$\frac{(3.85 - 2.24)}{8.55 - 3.85} \times \frac{100}{1}$

$= \frac{1.61}{5} \times \frac{100}{1}$

= 32.20% yellow

For Brown

$W_1 = 3.84g$

$W_2 = 8.84g$

$W_3 = 2.07g$

Lipid Content %=

$$\frac{(3.84 - 2.07)}{8.84 - 3.84} \times \frac{100}{1}$$

$$= \frac{1.77}{5} \times \frac{100}{1}$$

= 35.40% Brown

4.2.2 Crude Protein Content (%)

Correct titre value = 11.44ml

Nitrogen Content = 1.144%

Crude Protein Content (%)

= 6.25 x Nitrogen (%)

= 6.25 x 1.144

= **7.15%** for Yellow

For Brown

Correct titre value = 15.52ml

Nitrogen Content (%) = 1.552%

Crude Protein Content (%)

= 6.25 x 1.552

= **9.70%**

4.2.3 Ash content

For yellow

$W_1 = 11.13g$

$W_2 = 16.13g$

$W_3 = 11.33g$

Ash Content %=

$$\frac{(11.33 - 11.13)}{16.13 - 11.13} \times \frac{100}{1}$$

$$= \frac{0.2}{5} \times \frac{100}{1}$$

= 4.00% yellow

For Brown

$W_1 = 11.10g$

$W_2 = 16.10g$

$W_3 = 11.31g$

Ash Content %=

$$\frac{(11.31 - 11.10)}{16.10 - 11.10} \times \frac{100}{1}$$

$$= \frac{0.21}{5} \times \frac{100}{1}$$

= 4.20% Brown

4.2.4 Organic matter (%)

For yellow

$W_1 = 11.13g$

$W_2 = 16.13g$

$W_3 = 11.33g$

Organic matter Content %=

$$\frac{(16.13 - 11.33)}{16.13 - 11.13} \times \frac{100}{1}$$

$$= \frac{4.80}{5} \times \frac{100}{1}$$

= 96.00% yellow

For Brown

$W_1 = 11.10g$

$W_2 = 16.10g$

$W_3 = 11.31g$

Organic matter Content %=

$$\frac{(16.10 - 11.31)}{16.10 - 11.10} \times \frac{100}{1}$$

$$= \frac{4.79}{5} \times \frac{100}{1}$$

= 95.80% Brown

4.2.6 Percentage Carbohydrate (%)

% carbohydrate = % Organic Matter – (% protein + % Lipid)

For yellow

% Carbohydrate = 96.00 – (7.15 +32.20)

= 96.00 – 39.35

% Carbohydrate = 56.65% yellow

For Brown

% Carbohydrate = 95.80 – (9.70 +35.40)

= 95.80 – 45.10

= 50.70% Brown

Discussion of Results

From the results obtained for physical properties, the sizes of tiger Nuts were 12.28mm for major diameter, 10.54mm for intermediate diameter and 7.94mm for minor diameter, all for yellow Dried Tiger nut. For yellow wetted Nut – 13.72mm for major diameter, 12.21mm for intermediate diameter and 10.10mm for minor diameter. For brown dried Nut, the major diameter is 8.42mm, the intermediate diameter is 7.04mm and the minor diameter is 5.94mm.

These values show that the wetted tiger Nut is larger in size than the yellow dried and Brown dried Nuts. These values can find their application in the design of separating equipment such as greater, sieves and screens. Also, in the design of decorticating machines, the size of the wetted tiger nut is required for the determination of concave – beater clearance.

The value for sphericity for yellow dried nuts, yellow wetted Nuts and Brown dried nuts are 27.90, 41.11 and 13.94 respectively. This shows that yellow wetted Nuts are more spherical and also can roll more than other samples. The sphericity as one of the physical properties is an important parameter that determines the shape of tiger nuts which was confirmed from the chartered standards table (Mohserin 1984) to be oblong cylindrical in shape.

The weight for yellow dried Nut, yellow wetted nut and Brown dried Nut are $6.08x10^{-3}N$, $8.83x10^{-3}N$ and $1.96x10^{-3}N$ respectively. The weights of any agricultural materials vary with their sizes. The weight of the wetted tiger Nut is larger compared to other samples.

The Average Geometric Mean Diameter (AGMD) for the three (3) samples were 828mm for yellow dried Nut, 827 for yellow wetted Nut and 829mm for brown dried nut.

The surface areas for yellow dried, yellow wetted and brown dried Nuts were a $4.24x10^{-5}m^2$, $6.77x10^{-5}m^2$ and $1.03x10^{-5}m^2$ respectively. These values are very important in handling and processing of tiger Nuts. The surface area also helps in determining its drying ability and also its ability to mix with other constituents.

The volumes obtained from this experiment were $0.34cm^3$ for yellow dried nut, $0.50cm^3$ fro brown dried nut. From the result, the volume of the yellow wetted nut is higher than the volumes of other samples. To avoid occupation of space brown dried nut is desirable if it has to be stored.

The densities obtained were $1.82g/cm^3$, $1.80g/cm^3$ and $0.67g/cm^3$ for yellow dried nut, yellow wetted nut and brown dried nut respectively. The results shown that only brown dried nut can float on water since its density is less than that of water. Other will definitely sink when put in water since their densities are more than that of water. The parameters obtained from volume and density are important in the design of tiger nut drying equipment, storage structures and pneumatic devices.

The moisture contents obtained were 11.80%, 95.30% and 13.20% for yellow dried nut, yellow wetted nut and brown dried nut. The moisture content enables the state of the materials to be known at a particular in time during the experiment. The results

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from this experiment indicated that most of the properties depend on the moisture content.

From the results obtained fro chemical properties, the crude fibre content were gotten to be 6.50% for yellow nuts and 5.50% fro brown nuts. The values of lipid contents for yellow and brown nuts were 32.20% and 35.40% respectively.

The correct titre values for crude protein was 11.44ml, the nitrogen content was 1.144% fro yellow and 15.52ml and 1.552% fro brown. While the values crude proteins for yellow and brown were 7.15% and 9.70% respectively. This shows that a brown tiger nut is more proteineous than the yellow tiger nuts. The values of ash contents for yellow and brown tiger nuts were 4.00% and 4.20% respectively.

The values of the organic matters fro yellow and brown tiger nuts were 96.00% and 95.80% respectively. The percentage carbohydrates (%) for yellow and Brown tiger nuts were 56.65% and 50.70% respectively. This indicated that yellow tiger nuts contain more carbohydrate than the results obtained from most of these properties constitute important design parameters, which could be used in the design of tiger nut handling devices, drying equipment, storage structures and processing machines.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

Unlike other non-biological materials, agricultural materials in particular constantly undergo changes in shape, size, surface area, weight, moisture content etc. for physical properties and also change in crude fibre, crude protein, Ash content, lipid (fat) content as well as percentage of carbohydrate in the case of chemical properties, both at stage of development, processing and storage which are difficult to control. The unavailability, inadequacy, ineffectiveness, inefficiency and lack of proper maintenance of some of the equipment served as an obstacle to this research work. This seriously affected the accuracy of some of the physical and chemical properties.

However, most of the properties determined are within the stated range in similar literatures of agricultural materials like that of the Mohsenin (1984) standards. This will processing of tiger nut.

5.1 Recommendations

Considering the importance or uses of tiger nut in health wise and its consumption rate in Nigeria, at is important that more research work should be embarked on using this research work and the ones previously done as stepping stones.

It is therefore recommended that;

- The production of tiger nut should be encouraged in Nigeria by federal government.
- More research work should be conducted using other methods of the determination of some physical and chemical engineering properties of tiger nut.

- Finally, availability, adequacy, effectiveness and proper maintenance of some of the equipment for handling, storage and processing of tiger nut should be encouraged.

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