DETERMINATION OF SOME PHYSICAL PROPERTIES OF CASTOR SEED (*Ricinus communis*)

BY

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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 Information derived from personal communication, published and unpublished works of others were duly referenced in the text.

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Date

CERTIFICATION

This Project entitled "Determination of Some Physical Properties of Castor Seed" by Balogun, Mayowa Hammed 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.

13.11.2006

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DEDICATION

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

I also in special way dedicated this work to my parents, who have been praying to see the actualization of my Degree.

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ABSTRACT

This research work evaluated the basic physical properties of Agricultural materials and its utilities in machine and structural design, processes and control Engineering. In this research work, some physical properties of castor seed (shelled and unshelled) were determined. These physical properties and data include: shape (ovate), size (13.41mm, 10.89mm, 6.05mm), sphericity (0.71), roundness (1.22), weight (4.85N), diameter (0.6889mm), surface area (0.010249cm^2), volume (0.6cm^3), density (0.82g/cm^3) and 5.63% (db) moisture content for shelled nuts. Shape (ovate), size (15.10mm, 11.97mm, 7.18mm), sphericity (0.72), roundness (1.25), weight (5.69N), diameter (0.6684mm), surface area (0.01245cm^2), volume (0.8cm^3), density (0.72g/cm^3) and 7.30% (db) moisture content for unshelled nuts. 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.

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CHAPTER ONE

1.0 INTRODUCTION

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

In developing countries, this has been made possible by the application of modern technology which involves essentially the subjection of these materials to physical and mechanical treatment.

For machines, processes and handling operation to be designed for maximum efficiency and highest quality of the end products of plant and animal materials, their physical properties are required.

1.1 Physical Properties

According to Mohsenin (1970), 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 the following: shape and size, volume and density, surface area, roundness, sphericity, average geometric mean diameter and weight.

1.2 Castor Seed

Castor seed; which is also called *Ricinus communis* belongs to the family of Euphurbiaceae. It is a semi-tropical perennial grown extensively in warm-temperature and tropical region of the world. It is essentially a long-day plant, but can also adapt with some loss of yield to a fairly wide range of day length. Castor is an erect plant 1-3m tall. The stem may be green or reddish and have many leaf scars. They become hollow when mature. Leaves also have long stalks and large laminae with a saw-teeth margins. The seed colour may vary from white, brown and buff to black or red, usually several colours occurring as an attractive mottling on the testa. (Weiss, 1983)

Castor seed is classified as: Tall-normal internode and high node number, intermediate-normal internode and low node number, Dwarf-genetic- dwarf and with low node number (Post harvest Biotechnology of oilseeds). Brazil is the largest producer of castor seed, follow by India, China, USSR and Thailand. Castor seed contains the Castor oil and also various acidic compositions which enhances its utilization in the manufacture of many products. (FAO, 1981)

1.3 Objectives

The objective of this study is to determine some physical properties of castor seeds that are considered important for its handling, storage and processing.

These physical properties will include the following

i. Shape and size

ii. Volume and density

iii. Surface area

iv. Weight

v. Average mean diameter

vi. Sphericity

vii. Roundness

These properties when determined can be used for the design of handling devices, storage structures and castor seed processing machines.

1.4 Scope of Study

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

Also, the peculiarities of castor seed as a predominantly tropical agricultural material has not generated enough interest for sufficient research work hence the insufficient information in literature. In this study therefore, only those physical properties considered important for processing castor seed are determined.

1.5 Statement of the Problem

Machine and equipment designed for handling, processing and storage of some typical agricultural materials generally have low efficiency hence not economical. This is because the data on the physical properties of these tropical agricultural material required for the design of these machine and equipment are insufficient or in some cases are not available. For example, the production processes of castor-oil from castor seed are traditional, using very little or no modern technology thereby have low extraction efficiency and poor quality of oil. (FAO, 1981)

1.6 Justification

A research work in Kogi state where castor-oil is produced from castor-seed indicates that most of the processes are traditional, using little or no modern technology (FAO, 1981)

The extraction of castor oil by these methods is very low and generally of poor quality. The non-existing data on the physical properties of castor seed from literature may be considered as one of the major factors responsible for lack of modern processing technology for its oil.

In a nutshell, the need for the determination of physical properties of castor seed cannot be over-emphasized.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Castor Seed Species and Cultivars

There are species three species of castor, namely *Ricinus communis, Ricinus macrocarpus* and *Ricinus microcarpus.*the most commonly quoted subspecies are *Ricnus commounis persicus* (Persian subspecies), *Ricinus communis, Chinencis sanguineus (*Crimson subspecies), *Ricinus communis gibsoni* and *Ricinus communis cambogenesis* (Purplo subspecies).

Castor seeds are classified castor seeds as follow:

i. Tall-normal internode and high node number.

ii Intermediate-normal internode and low node,number.

iii. Dwarf-genetic dwarf. Usually with low node number.

2.2 Ecology, Botany and Structure of Castor Seed

Castor seed is a drought resistance crop, needing between 380-500mm of rain during a growing season of between 140-150 days. It does not tolerate heavy rainfall or water logging. Growing best on deep well-drained soils which encourage the development of a deep and therefore drought resistant root system. Temperature of greater than 40^0C during the flowering period result in poor seed set.

This species shows such wide diversity that some authority have define three distinct species. The wild plants and short-lived perennials growing up to 12m tall with a well developed tap root and laterals. The cultivated varieties are annuals, growing to a height of between 1 and 7m, the large laminate leaves are carried on leaf stalks coming from the main stem and branches and the male and female flowers are borne separately, with the male flowers found largely at the base of the plants.

The first is a globular capsule spiny to some degree becoming hard and brittle when ripe an occasionally shattering at maturity. Cultivated thorn-less varieties have rudimentary spines and other spines are soft, flexible and nonirritating. The capsule contain three seeds, a flattered oval in shape with a spiny brittle testa enclosing a white, highly oleaginous kernel. The seed vary greatly in size. . The 100-seed weight may vary from 10-100g, averaging about 30g in dwarfs. (Weiss, 1983)

2.3 Growth and Development of Castor Seed

Experiments have shown that oil formation in a dwarf hybrid castor grown in Canada began 20 days after blossoming and two-thirds of the total oil content is being synthesized in the next 20-days period. Protein synthesis occurred over a long period than that required for oil, but it was accelerated during the middle 20-days period. Ricinoleic acid was not present in very young seed, but appeared when the seed was 12 days old, and at 36 days of age, it represented 90% of the fatty acids. The fatty acid composition remained constant thereafter. The percent of each fatty acid increase over an entire period of development and there was no evidence for substantial conversion of Oleic and linoleic to ricinoleic acids (Weiss, 1983)

2.4 Castor Seed Production and Its Uses

According to FAO 1981, the world production of castor seed was 844 thousand metric tonnes (mT) from 1969 to 1971, which increased to 907 thousand metric tonnes (mT) in 1979 but decrease to 845 thousand metric tones in 1980. Brazil is the largest producer of castor seed, followed by India, China, the U.S.S.R and Thailand accounting about 85% of the global production of seed. India produces approximately 80,000mT of castor seed (oil) annually.

Table 1: Major Produces of Castor Seed in the World

Country	1969-1971	1978	1979	1980
Brazil	363	317	327	281
India	125	217	236	233
China	87	98	225	120
U.S.S.R	67	43	62	58
Thailand	40	43	37	26
World	844	852	907	845

(FAO, 1981)

The proximity of the hydroxyl group to the double bond in the ricinoleic acid molecules enables the castor oil for the manufacture of various products. The end uses of the castor oil are: Medicines, cosmetics, Lubricant, Coatings and disinfectants. Castor oil can also be used as a raw material in the manufacture of plasticides, adhesives, metallic soap, synthetic flavouring (perfumes) and also in the textile industries. (Weiss, 1983)

2.5 Harvesting, Handling and Maturity

Harvesting and handling are the most difficult and time consuming operations in castor growing, although suitable machines and varieties for large scale and mechanical operations are presently available. The first formed fruit ripen and begin to dry in about 120 to 150 days from planting, depending upon soil and variety. The normal practice is to harvest the crop when a few fruits show signs of drying. Delaying the harvest results in heavy loss due to dehiscence of mature capsules and consequent shedding of the seeds, if harvesting is done after all the fruits have dried. Mechanical harvesting consists of removing seed capsules from standing plants, using a beater mechanism that strikes plants directly under the lowest raceme. (Weiss, 1983)

It is important to maintain correct working speed by adjusting the machinery frequently. The number or amount of seed remaining on the surface of mechanical harvested fields is related to both plant height and speed of the harvesting machine. Most harvesters are designed to operate when the relative humidity is below 45% as moist capsules may remain attached to racemes and do not hull easily.

Harvesting of seed crops required great care and special skill in operating combines. Hand or manual harvesting may be preferred in smaller plots. Hulling can be mechanical, provided they are run at slow speeds, feeding dry capsule regularly. Hulled seed should be sorted immediately to remove the damaged ones.

After harvesting, castor plants should be destroyed, preferably by burning, to reduce the subsequent insect and disease infestation. Clusters reappeared slightly green or with wet capsules must be dried before hulling. Sun drying may be employed for this purpose. Prolonged exposure to sun or heat may affect the oil content of seed. Uniform density is required to be maintained while loading a drier with capsules of high moisture content to enhance efficiency of drying. Drying of unshelled castor with moisture content varying from 14.4 to 34.4% will not produce significant chemical change, although the acid value will be altered to some extent. (Weiss, 1983)

The harvested produce is usually stored in gunny bags or in bamboo baskets. Experiments have indicated that whatever, the method of storage, whether in bags baskets or in the open the most efficient and economical method of harvesting and processing castor bean begin when a few capsules of the fruit clusters shown signs of drying. (Chakravety, 1982)

2.6 Post Harvest Losses of Castor Seed (Pest and Diseases)

Castor is attacked by a variety of pest and diseases, causing a several decrease in yield and quality. Agrotis (Eunoa) cut worm: Crickets (gryllatalpa sp, brachytrupes sp and Gryllus sp): Flee beetles (Apluhona Whitefield, Bry (Sudan). Hermaeophage ruticollis Lus (Israel). Stem borers (Ostrinia nubilalis Hb, Xylentes capensis (Africa), Sphenoptera arabica and ardens Klug (Sgypt), Fulaens Gory (Sudan) and Xyleboras Foricatus Eichb (Ceylon) and a number of other pests like jassids, leafhoppers and Whiteflies attack the castor plant including inflorescences and seed.

Few pest attack stored castor seed if the testa is unbroken but damaged seed and press cake can become affected. The most common storage insect pests include the tropical warehouse beetle, cigarette beetle and red flour beetle.

An important disease attacking the castor flower and fruit is capsule mold caused by alternaria ricini. Seed and seedlings are also attacked by various roots rots and seedling blight, bacterial leaf spot, leaf rust, capsule borer, castor hair caterpillar caused heavy losses of castor seed production. (Chakravety, 1982)

2.6.1 Chemical Control of Post Harvest Losses

Dusting with 10% BHC of DDT, when caterpillars are young, or spraying 0.02% endrin control the castor semilooper. Spraying or dusting with BHC effectively control the castor capsules borer and the castor hairy caterpillar. Spraying with Bordeaux mixture or coppers fungicides effectively control several disease of the castor such as seedling blight and leafspot.

Spraying of endrin emulsion 0.15 1b active ingredient per acre, effectively control the castor semilooper. In area where spraying cannot be done dusting with 10% BHC or DDT is recommended. (Chakravety, 1982)

2.6.2 Storage of Castor Seeds and Its Oil

Castor seed are large and occupy considerable space in the storehouse in relation to their weight. Unlike bagged groundnut, castor seed cannot be stored in the open except for short period as both heat and sunlight reduced oil content and quality. The castor seed must be bagged carefully and handled properly.

Crude castor oil is generally stored for a long period. The colour and acidity of crude castor oil stored at high atmospheric temperature do not increase appreciably even after 1-month storage. Refined castor oil can be stored for up to 6-months to 1-year with little change in colour or acidity. Both crude and Refined castor oil can be stored for 1 to 2 years without accumulation of peroxide in significant amounts or increasing the oxidative rancidity. (Weiss, 1983)

2.7 Castor Oil Processing

The Traditional Processes: Castor seeds undergo various traditional processes in the cause of its preparation for extraction. The traditional processes make use of little or no modern technology, hence poor quality of oil extraction. Traditionally, the seed is separated from the spiny husk by sun drying in the open until the casing splits. The split castor seeds contain some foreign materials which are separated by hand picking. The shelling process is always manual, which involves the use of hand shelling. The castor beans are further crushed into paste (cake) form using mortar and pestle. The seeds contain between 40-55% oil which is extracted by boiling the crushed seeds in water and allowing the oil to float to the surface where it is schemed off.

The Modern Processes (methods): Castor seeds are subjected to various unit operations before the use of various modern methods of its oil extractions. The unit operations involved are: cleaning, drying, winnowing and grinding. The ripe seeds need to be cleaned, decorticated, cooked and dried prior to extraction. The methods being used in the extraction of castor oil from castor seed are: continuous screw press-expeller, hot pressing, solvent extraction and cold pressing. Most of the castor extraction methods occur on a batch or continuous basis. The first stage of extraction, which is also more economical, is the pre-pressing using a high pressure continuous screw press-expeller. The expeller usually consists of a barrel containing a stainless steel helical screw. The pitch of the screw flights gradually decreases towards the discharged end, to increase the pressure on the pump as it is carried through the barrel. Extracted oil is filtered, and collected in a settling tank. Material discharged from the press, called cake; contain 8 to 10 percent oil. It is crushed into coarse meal, and subjected to solvent extraction with hexane or heptane. Continuous pressing is used, based on the principle of counter current flow of solvent and oil bearing material. The oil is removed effectively, as the material comes in contact with increasingly purer solvent. After the extraction the solvent is removed by distillation. Hot pressing via hydraulic presses extract between 75 and 85% of the oil contained in castor bean, while the remaining press cake has about 12% oil content. Subsequent solvent extraction yields the bulk of the remaining oil together with 1 to 2% oil. Cold pressing is of sufficient high quality for immediate end uses, but oil from both hot hydraulic pressing and solvent extraction requires refining. (Weiss, 1983)

2.8 Castor Oil Fatty Acid Compositions

The use of castor seed (oil) is based on the constituent of fatty acid composition in the castor oil. According to British Standard Specification (BSS), typical fatty acid constituent in the castor oil are: ricinoleic, Linoleic, oleic, stearic palmitic, dihydroxystrearic, eicosanoic, and linolenic. (Weiss, 1983)

The castor oil fatty constituents and percentages are further tabulated in the table below.

Table 2: Fatty Acid Compositions in Castor Oil

Fatty acids	Percentages
Ricinoleic	89.5
Linoleic	4.2
Oleic	3.0
Stearic	1.0
Palmitic	1.0
Dihydoxystearic	0.7
Eicosanoic	0.3
Linolenic	0.3

(Weiss, 1983)

Table 3: International Specifications of Castor Oil

Characteristics	British Standard	U.S Standard
Acid value	4(max)	3(max)
Saponification value	177-187	179-185
Iodine value	82-90	82-88
Reichert-meisslvalue	-	-
Polensake value	-	-
Acetyl value	140(min)	-
Hydroxyl value	156	-
Unsaponifiable matter	1.0(max)	0.5(max)
Refractive index 20^0C	1.477-1.481	-
Refractive index 40^0C	-	-
Specification gravity 15.5^0C	0.958-0969	0.961-0.963
Colour	2.2y-0.3R(max)	3(max)
Critical solution temperature in ethanol	below 0^0C	-

(Weiss, 1983)

2.9 Physical Properties

According to Mohsenin (1970), the physical properties include; shape and size, volume and density, surface area, weight, average geometric mean diameter, roundness, sphericity. Therefore it is important to know the physical properties of plant and animal materials.

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 Screens.

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.

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 material, the easier it is to cool, dry, mix with other constituent e.t.c

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 consideration in designing.

5. **Sphericity:** The geometric foundation of the concept of sphericity rest upon the iso-perimetric property of a sphere. Different agricultural products have different sphericity. This bases is applicable in designing.

CHAPTER THREE

3.0 MATERIALS AND METHODS

The materials and test procedures use for the determination of the under-listed properties are as follows.(All the experiments were conducted using five selected samples for the shelled and unshelled Castor seeds and the values obtained were established in details in the discussions of results)

3.1 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 (1970). Some of them include:

i. Use of chartered standards

ii. Use of resemblance to geometric shapes

iii. Use of overhead projector/shadow graph

iv. Measurement of dimensions on three mutually perpendicular axes

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

Shape: To determine the shape of castor seed, tracing of the longitudinal and lateral cross section of the Castor seeds shelled and unshelled 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 (Castor seeds) over five replicates.

Size: To determine the size of the Castor seed diameter according 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 shelled and unshelled 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 five samples were now determined in order to obtain the average of the three axes i.e. (the major, intermediate and minor diameters). The procedures were done for both shelled and unshelled nuts

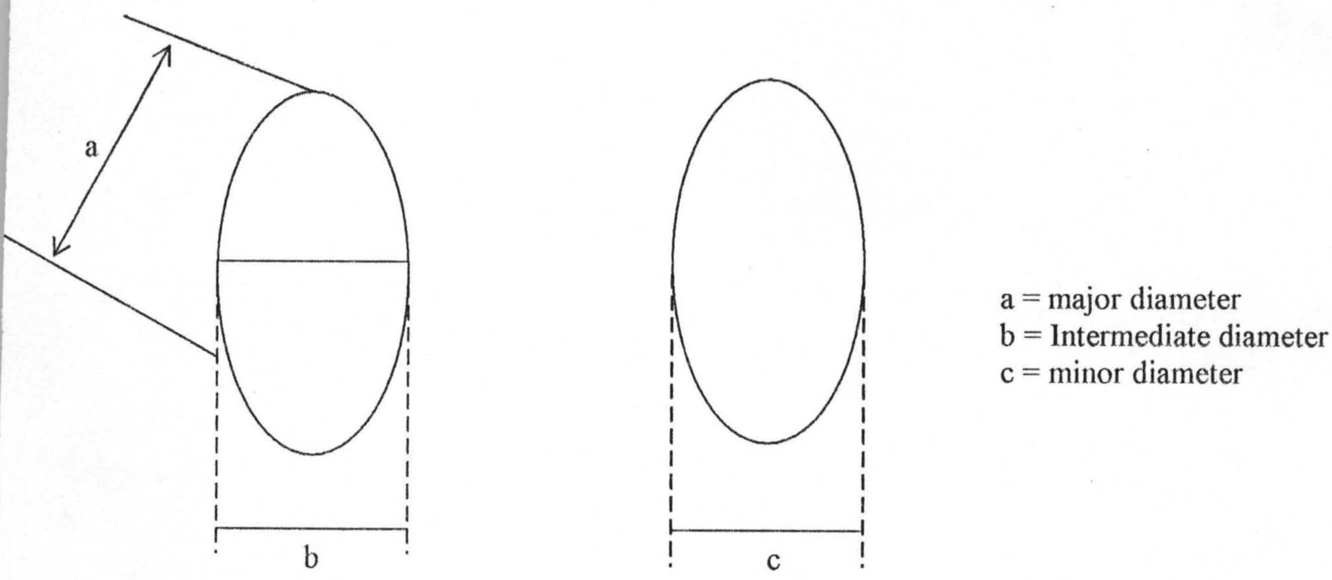

Fig 1: Determination of the principal dimensions of Castor seed

3.2 Sphericity

According to Mohsenin (1970), 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 shelled and unshelled nuts. The values were substituted into the stated formula below.

$$Sphericity\ \ S = \frac{[abc]^{\frac{1}{3}}}{a} = \frac{Geometric\ Mean\ \ diameter}{Major\ diameter} \quad \text{(Mohsenin, 1970)}$$

Where

a = major diameter of the castor seed

b = intermediate diameter of the castor seed

c = minor diameter of the castor seed

3.3 Weight

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

The weight was calculated using the relationship

Weight (W) = Mass x Accelerated due to gravity

W = mg

These were done for both shelled and unshelled nuts

3.4 Roundness

According to Mohsenin (1970), the roundness of any agricultural product can be 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 object area is obtained either by projection or tracing. The Castor seeds area were obtained by tracing.

The largest projected area of the castor seeds (shelled and unshelled) in natural rest position and their small areas of circumscribing circle were determined over the five selected replicate. The roundness ratios were obtained accordingly.

3.5 Average Geometric Mean Diameter

Gupta and Das (1997), Olajide and Ade-omowaye (1999) and Jan and Bal (1997) calculated the geometric mean diameter of sunflower seeds, locust bean seeds and pearl millet by the following formulas respectively;

$$De = (LBT)^{\frac{1}{3}}$$

$$Dp = (LWT)^{\frac{1}{3}}$$

$$D = (D_2D_3)^{\frac{1}{3}}$$

Alabadan, B.A calculated the geometric mean diameter of cowpea using this empirical formula (Physical properties of selected Biomaterials as Related to their Post-Harvest Handling, 1999)

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

Where

D = Average Geometric mean Diameter

W = Weight of the Agricultural Material

The weights of castor seeds (shelled and unshelled) were obtained using the electronic weigh balance and the mean values of the weights were substituted into the stated formula ($D = 0.83\, e^{-0.38W}$)

3.6 Surface Area

Methods for determination of surface area or agricultural materials such as leaf, fruits and egg as listed by Mohsenin (1970) include;

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

ii. The Use of shadogragh

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

iv. 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.

v. Coating the surface of the sample 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 formular

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

Where

S = Surface area of the agricultural Material

W = Weight of the agricultural Material

The weights of castor seeds (shelled and unshelled) were obtained using the electronic weigh balance and the mean values of the weights were substituted into the stated formula ($S = 0.025W^{1.25}$)

3.7 Volume and Density

Volume and Density play important roles in many applications as earlier mentioned. Methods for determination of volume and density as listed by Mohsenin (1970) include:

i. The use of Platfoam scale

ii. Air compression Pychometer for solid particles

iii. Resemblance to a geometric shape e.g fresh egg is assumed to be prolate spheroid shape hence volume is calculated from the expression $V = \frac{4}{3}\pi(ab^2)$

iv. Water displacement method for non-water objects.

The volumes of the nuts were determined by the water displacement method. Because unshelled nuts (castor seed nuts) float on water, a small metal bob (pendulum bob) was used as a sinker.

Water was poured into a $1000cm^3$ 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 nut was then tied with a light inextensible string to the sinker and both immersed in water. The difference between the final and the 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 unshelled nuts. The same procedure is followed for shelled nut of the castor seed.

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

$$\text{Density } (\rho) = \frac{mass}{volume}$$

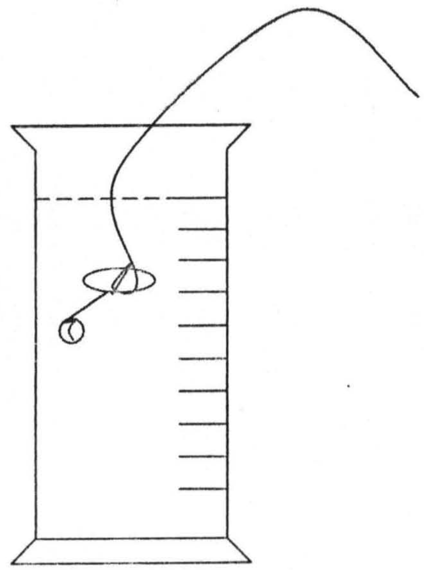

Fig 2: Volume determination using water displacement method

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

According to Mohsenin (1970) physical properties are parameters which depend on the moisture contents of the agricultural materials. The determinations of the moisture content parameters, help us to know the state of the materials at the time of the experiment.

For this research work, the electrical oven-dry method was used with moisture content calculated on dry basis, conforming to standard stipulated for oil seeds by the American Society of Agricultural Engineers ASAE standards (1989)

Table 4: Moisture Content Determination on Dry Basis

	Shelled Castor Seed		**Unshelled Castor seed**	
	Can	**Can + Seed**	**Can**	**Can + Seed**
Initial Weight (g)	9.79	24.79	9.62	24.62
Final Weight (g)	9.79	23.99	9.62	23.60

$$\text{Moisture content (dry basis)} = \frac{\text{Initial weight - final weight}}{\text{Final weight}} \times \frac{100}{1}$$

The moisture content (Mc) for the shelled nut castor seed is 5.63% (db)

The moisture content (mc) for the unshelled nut castor seed is 7.30% (db)

The results obtained below are the mean value obtained over five replicates of the product to obtain the selected physical properties.

Shape and Size

Shape: Comparing the shape with those shapes listed by Mohsenin in the chartered standard, it was confirmed that castor seeds are ovate in shape

Size:

Table 5: Principal Dimensions Determination for Shelled Nuts

Samples	Major diameters (mm)	Intermediate diameters (mm)	Minor diameters (mm)
1	13.87	11.14	5.80
2	13.65	11.24	6.31
3	13.71	10.89	6.20
4	13.31	10.92	6.14
5	12.49	10.25	5.79

Major diameter (a): $\frac{13.87 + 13.65 + 13.71 + 13.31 + 12.49}{5} = 13.41mm$

Intermediate diameter (b): $\frac{11.14 + 11.24 + 10.89 + 10.92 + 10.25}{5} = 10.89mm$

Minor diameter (c): $\frac{5.80 + 6.31 + 6.20 + 6.14 + 5.79}{5} = 6.05mm$

Table 6: Principal Dimensions Determination for Unshelled Nuts

Samples	Major diameters (mm)	Intermediate diameters (mm)	Minor diameters (mm)
1	14.57	11.40	7.09
2	15.73	12.32	7.37
3	15.02	12.13	7.17
4	15.46	12.20	7.19
5	14.73	11.80	7.06

Major diameter (a): $\frac{14.57 + 15.73 + 15.02 + 15.46 + 14.73}{5} = 15.10mm$

Intermediate diameter (b): $\frac{11.40 + 12.32 + 12.13 + 12.20 + 11.80}{5} = 11.97mm$

Minor diameter (c): $\frac{7.09 + 7.37 + 7.17 + 7.19 + 7.06}{5} = 7.18mm$

Size: For shelled nuts; the major diameter is 13.41mm, intermediate diameter is 10.89mm and minor diameter is 6.05mm.

For unshelled nuts, the major diameter is 15.02mm, intermediate is 11.97mm and minor diameter is 7.18mm.

For the design of decorticating machine, sizes of the unshelled nuts are required for the determination of concave-beater clearance for effective shelling.

Sphericity

$$Sphericity\ \ S = \frac{[abc]^{\frac{1}{3}}}{a} = \frac{Geometric\ Mean\ \ diameter}{Major\ diameter}$$

Shelled nuts: $S = \frac{(13.41 \times 10.89 \times 6.05)^{1/3}}{13.41} = 0.71$

Unshelled nuts: $S = \frac{(15.10 \times 11.97 \times 7.18)^{1/3}}{15.10} = 0.72$

For shelled nuts, the sphericity is 0.71 for the unshelled nuts, the sphericity is 0.72. this shows that, unshelled nuts is more spherical than shell nut. This implies that unshelled nut can roll more than shelled.

Roundness

Table 7: Roundness Determination for Shelled Nuts

Samples	AP	AC
1	13.60	11.13
2	13.24	11.07
3	13.67	10.88
4	13.68	11.25
5	12.56	10.21

$AP = \frac{13.60 + 13.24 + 13.67 + 13.68 + 12.56}{5} = 13.35$

$AC = \frac{11.13 + 11.07 + 10.88 + 11.25 + 10.21}{5} = 10.908$

$Roundness = \frac{AP}{AC} = \frac{13.35}{10.908} = 1.22$

Table 8: Roundness Determination for Unshelled Nuts

Samples	AP	AC
1	15.76	12.23
2	14.50	11.83
3	15.48	12.18
4	14.70	12.14
5	14.10	11.14

$$AP = \frac{15.76 + 14.50 + 15.48 + 14.70 + 14.10}{5} = 14.908$$

$$AC = \frac{12.23 + 11.83 + 12.18 + 12.14 + 11.14}{5} = 11.904$$

$$\text{Roundness} = \frac{AP}{AC} = \frac{14.908}{11.904} = 1.25$$

For shell nuts, the roundness is 1.22. For the unshelled nuts, the roundness is 1.25

Weight

Shelled nuts:

The mass of selected five samples was 2.45g

$$\text{The mean value obtained} = \frac{2.45}{5} = 0.49g$$

Weight = Mg

$$= 0.49 \times 9.89 = 4.85N$$

Unshelled nuts:

The mass of selected five samples was 2.88g

$$\text{The mean value obtained} = \frac{2.88}{5} = 0.576g$$

Weight = Mg

$$= 0.576 \times 9.89 = 5.69N$$

The mean overall weight of the material for this study is; for the shelled nuts, the weight is 4.85N. For the unshelled nuts, the weight is 5.69N.

In summary, unshelled nuts are heavier than the shelled nuts.

Geometric Mean Diameter

Shelled nuts:

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

$$D = 0.83e^{-0.38 \times 0.49}$$

$$D = 0.6889mm$$

Unshelled nuts:

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

$$D = 0.83e^{-0.38 \times 0.576}$$

$$D = 0.6684mm$$

For shelled nuts, the diameter is 0.6889mm. for unshelled nuts, the diameter is 0.6684mm for this experiment.

Surface Area

Shelled nuts:

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

$$S = 0.025 \times 0.49^{1.25}$$

$$S = 0.010249cm^2$$

Unshelled nuts:

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

$$S = 0.025 \times 0.576^{1.25}$$

$$S = 0.012545cm^2$$

The overall average result for this study is, for the shelled nut, the surface area is $1.0249 \times 10^{-2} cm^2$. For the unshelled nuts, the surface area is $1.2545 \times 10^{-2} cm^2$

Volume

The volumes were obtained by water displacement method and the values for both shelled and unshelled recorded accordingly.

Shelled nuts:

Initial volume of water = $130cm^3$

Final volume of water = $133cm^3$

Volume of the shelled castor seed = $(133 - 130)cm^3 = 3cm^3$

$$\text{Mean value} = \frac{3\ cm^3}{5} = 0.60cm^3$$

Unshelled nuts:

Initial volume of water = $130cm^3$

Final volume of water = $134cm^3$

Volume of the shelled castor seed = $(134 - 130)cm^3 = 4cm^3$

$$\text{Mean value} = \frac{4\ cm^3}{5} = 0.80cm^3$$

For shelled nuts, the volume for this experiment is $0.60cm^3$. For unshelled nuts, the value is $0.80cm^3$

To avoid occupation of space, it is better to shell the nuts if it has to be stored.

Density

The electronic weighing balances were used to obtain the mass of both the shelled and unshelled castor seeds; the averages were taken accordingly.

Shelled nuts:

Mass = 0.49g

Volume = $0.6cm^3$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{0.49\,g}{0.6cm^3} = 0.82g/cm^3$$

Unshelled nuts:

Mass = 0.576g

Volume = $0.8cm^3$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} = \frac{0.576\,g}{0.8cm^3} = 0.72g/cm^3$$

For shelled nuts, the density is $0.82g/cm^3$. For unshelled nuts, the density is $0.72g/cm^3$

This means that shelled and unshelled nuts will float on water since the densities of the nuts are less than that of water (density of water = $1g/cm^3$).

The data obtained form the experiment, for the shelled and unshelled are further tabulated in table 9 and table 10 respectively.

Table 9: Shelled Nuts

Properties (Physical Properties)	Mean Values of the Parameters
Shape	Ovate
Size (mm)	
a. Major diameter	13.41
b. Intermediate diameter	10.89
c. minor diameter	6.05
Sphericity x 100	71
Roundness	1.22
Weight (N)	4.85
Geometric Mean Diameter (mm)	6.889×10^{-1}
Surface Area (cm^2)	1.0249×10^{-2}
Volume (cm^3)	6.0×10^{-1}
Density (g/cm^3)	8.2×10^{-1}
Moisture content (%)	5.63

Table 10: Unshelled Nuts

Properties (Physical Properties)	Mean Values of the Parameters
Shape	Ovate
Size (mm)	
a. Major diameter	15.10
b. Intermediate diameter	11.97
c. minor diameter	7.18
Sphericity x 100	72
Roundness	1.25
Weight (N)	5.69
Geometric Mean Diameter (mm)	6.684×10^{-1}
Surface Area (cm^2)	1.2545×10^{-2}
Volume (cm^3)	8.0×10^{-1}
Density (g/cm^3)	7.2×10^{-1}
Moisture Content (%)	7.30

Discussions of Results

From the results obtained, the sizes of castor seeds were 13.4mm for major diameter, 10.89mm for intermediate diameter and 6.05mm for minor diameter for the shelled nut. 15.10mm for major diameter, 11.79mm for intermediate diameter and 7.18mm for minor diameter for the unshelled nut. These values show that the unshelled castor seed is larger in size than the shelled seed. These obtained values can be applicable in the design of separating equipment such as graters, sieves and screens. Also, in the design of decorticating machines, the size of the unshelled nut is required for the determination of concave-beater clearance for effective shelling.

The sphericity values obtained for the experiment were 0.71 and 0.72, for the shelled and unshelled castor seeds respectively. This indicates that unshelled is more spherical and also can roll more than the shelled nut. The roundness for the castor seeds (shelled and unshelled) were 1.22 and 1.25 respectively. The roundness and sphericity obtained are important parameters that determined the shape of the castor seeds, which was confirmed from the chartered standards table to be ovate in shape.

The weights of any agricultural materials vary with their sizes. Therefore, the weight of unshelled seed from the obtained value was 5.69N, which was higher than 4.85N obtained for the shelled seed. Hence, it would not be appropriate to find an average weight of a seed. The geometric mean diameters for this experiment were 0.6889mm for shelled nut and 0.6684mm for unshelled nut respectively. The surface areas for the shelled and unshelled for this experiment were 0.01249cm^2 and 0.012545cm^2 respectively. These values obtained are very important in handling and processing of castor seed. The surface area also helps in determining its drying ability and also its ability to mix with other constituents.

The volume obtained from this experiment was obtained using water displacement method for the shelled and unshelled nuts. $0.60cm^3$ for shelled nut and $0.80cm^3$ for the unshelled nut. From the result derived, the volume of the unshelled is higher than the shelled nut. To avoid occupation of space, it is better to shell the nuts if it has to be stored. The densities obtained were $0.82g/cm^3$ for shelled and $0.72g/cm^3$ for unshelled. The results show that both the shelled and unshelled castor seeds nuts will float on water. This is because, their densities are less than that of water. The parameters obtained from volume and density are important in the design of castor seeds drying equipment, storage structures and pneumatic devices.

The moisture contents were determined using electrical oven-dry method on dry basis for the shelled and unshelled seeds. The moisture contents were 5.63% for shelled and 7.30% for unshelled respectively. The moisture content enables the state of the materials to be known during the experiment. The results from this experiment indicated that most of the properties depend on the moisture contents. The results obtained from most of these properties constitute important design parameters, which can be used in the design of castor seed handling devices, drying equipment, storage structures and processing machines.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

Unlike other non-biological materials, agricultural materials constantly undergo changes in shape, size, weight, surface area, moisture content e.t.c both at stage of development and storage which are difficult to control. The unavailability, inadequacy and ineffectiveness of some of the equipment made this work to prove some difficulties. This hitherto affected the accuracy of properties determined.

However, most of the properties determined are within the range stated in similar literatures of agricultural materials. This will assist the seed in its proper handling during transportation, storage and processing.

5.2 Recommendations

Considering the potentials of castor seeds in Nigeria economy if fully utilized, it is important that intensive work should be done, using this research work as a foundation and other compile research findings.

I therefore recommend that more research work should be conducted using other methods of the determination of some physical engineering properties of castor seeds.

REFERENCES

Alabadan, B.A (1999): Physical Properties of Selected Biomaterials as Related to their Post- Harvest Handling. Department of Agricultural Engineering Federal University of Technology, Minna.(pg 328-330)

ASAE Standards (1989): Standard Engineering Practices and Data. America Society of Agricultural Engineers. (pg 365)

Chakravety. A (1982): Post Harvest Technology of Cereals, Pulses and Oilseeds.

FAO (1981): Food and Agricultural Organization Production Year Book, Rome. Volume 34.

Gupta, R.K and Das, S.K (1997): Physical Properties of Sunflower Seed. *Journal of Agricultural Engineering Research.*(pg 66,1-8)

Jain, R.K and Bal, J S (1997): Properties of Pearl Millet. *Journal of Agricultural Engineering Research,(* pg 66, 85-91)

Mittal, J. P (1983): Design-Related Physical Properties of selected Agricultural Products. Agricultural mechanization in Asia, Africa and Latin America. (pg 59-62)

Mohsenin, N.N (!970): Physical Properties of Plant and Animal Materials. Gordon and Breach Scientific Publishers New York.

Mohsenin, N.N (!984): Physical Properties of Food and Agricultural Materials. A Teaching Manual. Gordon and Breach Scientific Publishers New York.

Weiss, E. A (1983): Oilseed Crops. Tropical Agricultural Science, Longman London.

Plate 1: Unshelled castor seeds samples

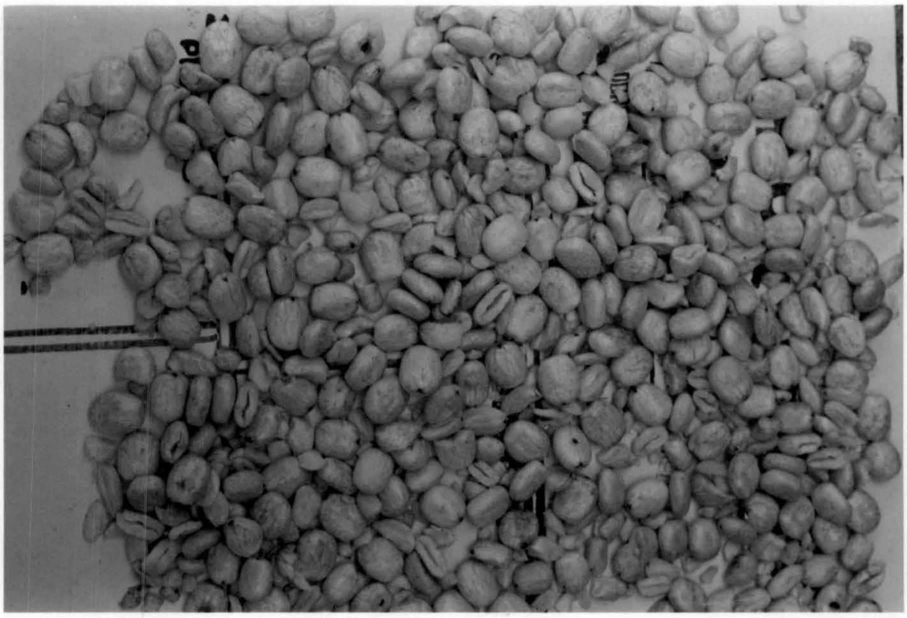

Plate 2: Shelled castor seeds samples

Plate 3: Sample in oven (moisture content determination)

Plate 4: Weight determination using electronic weighing balance