DETERMINATION OF ENGINEERING PROPERTIES OF AFRICAN LOCUST BEAN

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DECLARATION

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

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20/02/2012

Date

CERTIFICATION

This is to certify that the project entitled Determination of Engineering Properties of African locust bean by Aboyeji Olanrewaju Seun meets the regulation governing the award of the degree of Bachelor of Engineering (B. ENG.) of the Federal University of Technology, Minna, and it is the approved for its contribution to scientific knowledge and literally presentation.

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DEDICATION

This project work is dedicated to God Almighty and Aboyeji's family.

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ABSTRACT

African Locust bean was found to be a protein rich crop whose seed is processed into local food condiment 'iru' in Nigeria. To explore the possibility of developing handling and processing equipment for the seed, some engineering properties namely: size, shape, colour, volume, 1000 seed weight, true density, bulk density, porosity, angle of repose, surface area coefficient of friction on glass, plywood, and galvanized steel metal, and compressive strength, of samples from three different states were studied. The three states are Kogi, Niger and Oyo states. Analysis of variance (ANOVA) showed that three was significant difference within the samples in size, seed weight, surface area, compressive strength, while there was no difference in volume, densities and porosity. Force of 50 KN was used to compress the seeds, at speed of 100, and the results shows that the seeds from Kogi state had maximum elongation of 13.78 mm at break load of 13.09 KN, seeds from Niger state had maximum elongation of 6.87 mm at break load of 12.07 KN, while seeds from Oyo state had maximum elongation of 7.73 mm at break load of 10.11 KN. There was significant difference between the values of the compressive strength. From the result it can be concluded that the force required for mechanical dehulling process might vary for the seeds from the three different states.

Keywords: Locust bean; Parkia biglobosa; Physical properties; Mechanical properties; Compressive strength

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CHAPTER ONE

1.0 INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Modern agriculture has brought about the handling and processing of plants and animal materials by various means ranging from mechanical, thermal, electrical, optical, to even sonic technique. Upon all these ever increasing application, little information is available on the basic engineering properties of these materials, particularly in Nigeria. The ever increasing importance of agricultural products together with the complexity of modern technology for their production, processing and storage need a better knowledge of the engineering properties of these products. It is however necessary to understand the physical laws guiding the response of these agricultural products so that machines, processes and handling operations can be designed for maximum efficiency and the highest quality of the final end products (Mohsenin, 1970). Agricultural products especially those of the plant origin are now frequently used for a wide range of activities with importance of other increasingly emerging products. These agricultural products have over the years been underexploited in the regions of which they are produced especially in the developing countries. The multifunctional use of locust bean makes it a necessity to determine the engineering properties of this extremely valuable agricultural product so that more extensive study can be conducted in order to determine and locate more areas of which the locust bean is relevant. The economic importance of food materials tends to increase greatly with the complexity of new technology for the handling, production, processing, storage, preservation. Evaluation in quality, distribution and marketing; and their various uses depends on, and demands the knowledge of the engineering properties of these materials. Processes or handling operations can be designed to produce optimum efficiency and the maximum quality of food or end products. For instance, the application of physical properties such as shape is an important parameter in developing of sizing and grading machines and for analytical predictions of its drying behaviour (Esref and Halil, 2007). Density, size, and drag coefficient are important in the calculation of terminal velocity of an object in fluid (Alemede, 1994) Kachru *et al.* (1994) reported that it is essential to determine the physical properties of oil seeds (for example peanut) for proper design of equipment for handling, conveying, separation, dehulling, drying, aeration and mechanical expression of oil from these seeds. It has been established that moisture content affects the physical properties of seeds appreciably (Desphande *et al.,* 1993; Singh and Goswami, 1996). Knowledge of mechanical properties (properties that have to do with the behaviour of agricultural products under applied forces) such as stress, strain, hardness and compressive strength is vital to engineers handling agricultural products. The determination of engineering properties of agricultural products under static or dynamic loading is aimed at textural measurement of unprocessed and processed food materials; the reduction of mechanical damage to agricultural produce during postharvest handling, processing, and storage; and the determination of design parameters for harvesting and postharvest systems (Anazodo, 1983). Therefore, the knowledge of the engineering properties of the products is important in the design of agricultural machinery, equipment and facilities.

1.2 DESCRIPTION OF AFRICA LOCUST BEAN

Africa locust bean (Parkia Spp) is one of 34 known species of the Genus Parkia, whose origin is traced to South America. The four most commonly used species are Parkia bicolor, Parkia clappertoniana, Parkia fillicoida and Parkia biglobosa. It is an agro forestry tree species of the family of Minnesacesse (a leguminous group) spread throughout the African Sudanian savannah, from the Senegal in the west to Uganda in the east (Kudabo et al; 1999). Africa locust bean tree is about 30m high and its diameter range from 0.95m to 1.85m. It bears bipinate leaves and dark red and spherical shaped flower heads about 5cm (0.5m) in diameter. It is an insect pollinated plant that bears numerous pods. It flowers between the months of December and January and fruits between the months of January and February. Leaves are usually shed as the fruits mature and new ones appear. The fruit are green when immature and brown when mature and grows on the tree which is harvested by plucking from the tree between the months of March and May. The fruits usually grow in pods. There is a yellow pulp inside the pod and embedded inside the pulp and two types of seeds, the dark brown and reddish brown seed. Each pod usually contains two to ten seeds. The seeds are fermented and used as food condiment called "IRU" in Yoruba, "OGIRI" in Igbo and "DAWADAWA" in HAUSA, (Onyenya 1968). Africa locust bean tree is a naturally occurring tree and grows within the Savannah region of Nigeria.

1.3 STATEMENT OF THE PROBLEM

The local method of processing, the shortage of processing equipment, and inadequate preservative for locust bean, which maybe due to the fact that data on the engineering properties of locust bean required for the design of these equipment are insufficient or not available in some cases. Furthermore, most agriculture products are visco-elastic, hence, the determination of the engineering properties of biomaterials are difficult and complicated, since they are apparently affected by comparative moisture content, and the rate of loading (Zoerb and Hall, 1993, Saxena, 1992).

1.4 OBJECTIVE OF THE STUDY

The general objectives of this study is determine some engineering properties of locust bean grown in two agro-ecological regions of Nigeria

The specific objectives are:

1. To determine some engineering properties of Parkia biglobosa obtain from three different state (Kogi, Niger and Oyo states)

2. To determine how these properties vary with these regions.
3. To ascertain if these variation are statistically significant.

1.5 JUSTIFICATION OF THE STUDY

The knowledge of the engineering properties is useful for both engineers and food scientists, plant and animal breeders, and as thus, these data are of high importance in the design and fabrication of machine used in harvesting, processing, handling and preserving of locust bean for different functions and purposes of which the African locust bean had been underutilized, particularly in the developing countries.

1.6 SCOPE OF THE STUDY

The properties of biomaterials can be broadly classified by physical, chemical, mechanical, thermal, electrical and optical properties. However, this study is limited to the determination of some selected engineering properties of African locust bean grown in two agro-ecological regions of Nigeria so as to establish a convenient reference data for their mechanization and processing. Such properties include size, shape, colour, seed weight, volume, particle density, bulk density, porosity, surface area, angle of repose, coefficient of friction, and compressive strength.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 HISTORICAL BACKGROUND AND EVOLUTION OF LOCUST BEAN

The Parkia Spp is suspected to be specialized offshoot of the Ingea. The Ingea is a relatively advanced group of the mimosoideae, represented today by the mimoseae. Particular features of parkia, taken on advanced state within the mimosoideae are the pollen in payloads and a base chromosome number below 14. Reports of species have revealed that Parkia was present in Cameroon and Senegal. Other reports indicate older pollen fossils in Cameroon (mid and upper EOC: 50 -53 my BP). The fossils are known by the polynological name, Parkiidites Microreticulatus Guinea; (Hopkins, 1986) Robert Brown first named the Parkia spp in 1866, after the famous Scottish botanist and surgeon, Mungo Park who worked extensively in India and in the Nigeria Basin. He described the tree in 1799 during his tour in the interior districts of Africa. The African locust bean (Parkia spp) is an important indigenous multipurpose fruit tree in many African countries of the sub-Saharan Africa. It is the source of natural nutritious condiments, which features frequently in the traditional diet of the people of both rural and urban dweller in at least seventeen West African countries, including Nigeria (Hagos, 1992). As a result of age-long association with the traditional agriculture and diverse usage, it has attained protective status in most agricultural systems. The specific countries where the species occur naturally are the Republic of Benin, Burkina Faso, Cameroon, Ghana, Guinea Bissau, Ivory Coast, Mali, Niger, Nigeria, Sao Tome, Senegal, Sierra Leone, Sudan, Togo, Uganda and Zaire. In total, there are thirty species of Parkia, three of which are indigenous to Africa. They are Parkia biglobosa, Parkia bicolor and Parkia fillicoida. African locust bean seeds are fermented into paste to make condiment with a stray smell used in flavouring soups and stews. The condiments are variously called "Dadawa" in hausa, "Iru" in Yoruba and "Ogiri" in Igbo respectively in Nigeria. The estimated average consumption rates for the condiment per head for Nigeria, Togo and Ghana are 10g, 4g and 2g respectively (Odunfa, 1985).The distribution of locust bean tree in Nigeria is as follows: Abuja, Adamawa, Bauchi ,Benue, Gombe, Kaduna, Katsina, Kebbi, Kogi, Kwara, Lagos, Nasarawa, Niger, Ogun, Oyo North, Taraba, Yobe, Plateau and Zamfara.

2.2 DESCRIPTION OF LOCUST BEAN TREE

Africa locust bean tree is a deciduous tree and can grow to a height of up to 30 metres, although more usually, it is in the height range of 7.20metres. The bark is streaked with dark brown or black colour, it is thick which gives the impression of flaking in the adult tree. The trunk is stout and robust with no bitterness. The branches tend to develop a low-down on the trunk. The crown is large and wide and has been described as "fortement charpentee" which means "solidly constructed" (Busson, 1987). The wood is whitish and fairly heavy weighing 580-640kg. It is hard and solid but it has an unpleasant smell when newly felled which resembles that of onions, (FAO, 1988). Although the wood is easily worked on and moderately hard, it is of little commercial value as termites and fungus causes its decolouration. However, the wood has considerable domestic value. Africa locust bean tree has dark green leaves which are bi-pinnate, usually with a gland on the inside base of the radius. The primary radius is 20-40cm long and holds 30-60 pairs sub-opposite leaflets. These leaflets are 7-30mm long and 2-3mm wide and have a distinctive shape. The leaves close up at night. Leaf retention is high, especially in young trees. In mature trees, there is a sudden leaf fall in November to December preceding flowering but by January, new leaflets begin to grow. The pods are 15-30cm long and 1.5-2.0cm wide, when young they are green and fleshy but on maturity, they become pink or brown to dark brown, dry and fibrous, (FAO, 1988). Pods are attached by strips 5-10cm. Long pod development which involves the elongation of the pod and seed formation. The pods are elongated and flat in shape. The pods contain 42% pod case, 36% pulp and 22% seed. Locust bean has two types of seeds, reddish brown and dark brown (or black). Both occur in each pod and the ratio between their numbers varies from 1:20 to 1:5. The seed is flat and spherical (almost round in shape). The seed is covered with hard, smooth testa (seed coat) which makes the raw seed very hard and inedible. The hard, smooth testa protects the seed even when it passes through the guts of animals. It also makes the labour difficult during the dehulling of the seeds .The reddish brown seeds seem to have a thinner seed coat, while the dark brown seeds have a hard seed coat. Average weight of the seed is approximately 0.25g. The hard, smooth testa is surrounded by a yellow, flowery pericarp (pulp) which is very rich in vitamin C (Busson, 1987). The seed can be dispersed by man and animals, (Baker et al; 1997).

2.2.1 Description of Parkia bicolor

Parkia bicolor is from the forest of West and central Africa, parkia bicolor has large, reddish pendent flower heads that are pollinated by fruit bats at night. It is from the Leguminosae – Mimosoideae. It occurs in rain forest and swamp forest, usually in region with more than 2,000mm of rain per year. The tree is up to 35m tall (sometime even taller), with a tall bole (unbranched part of the trunk) about 1m in diameter, widely spreading buttresses and a well developed, briefly deciduous crown. The leaves are bipinnate (divided into leaflets which divided again), and up to 35 cm long. Each of the numerous pinnae bears 30 or more pairs of small, slightly curved leaflets. The individual flowers are small, and are massed into bluish-red or orange – red flower heads that are borne on tough, pendent stalks. In each flower head, fertile flowers form a round to elongated ball at the tip. The sterile flowers have long filaments which form a fringe at the base, and this fringe overhangs a ring of specialized nectar-secreting flowers in the middle. The fertile flowers have a 5-lobed corolla, 10 stamens (male part), and a single ovary with a long terminal style and about 20 ovules. The flowers open in late afternoon and last for one night. The pods (fruits) are up to 40cm long by 1.5-3.5 cm broad, twisted and strap-like but swollen over each seed. They hang in bunches in the crown, each bunch arising from the woody, central part of old flower head. The flattened seeds are 11-15 by 7-10 mm and surrounded by a small amount of yellowish floury pulp that is eaten by dispersers, such as monkeys, bats and also humans (Gruneier, R. 1990; Hopkins, H.C. 1983; Hopkins and White, 1984).

2.2.2 Description of Parkia Biglobosa

Parkia biglobosa is a perennial deciduous tree with a height ranging from 7 to 20 m, although it can reach 30m under exceptional conditions. Crown large, spreads wide with branches low down on a stout bole; amber gum exudes from wounds; bark dark grey brown, thick, fissured. Leaves alternate, dark green, bipinnate to 30 cm long, pinnae up to 17 pairs with 13-60 pairs of leaflets, 8-30 mm x 1.5-8 mm, of distinctive shape and venation. Leaflets held on a long rachis. Peduncles are 10-35 cm long; capitula 4.5-7 cm long and 3.5-6 cm in diameter, biglobosa but distal portion much larger. Hermaphrodite flowers orange or red in colour: calyx 10-13 (16 max.) mm; corolla 10-14 (17 max.) mm long, lobes very short 1-3 mm long, connate in the middle and free or connate t base; filaments exerted about 4 mm beyond calyx mouth. Nectar-secreting flowers: calyx about 6-7 mm long. Staminodial flowers; calyx about 5.5-7 mm long, filaments exerted 23mm beyond calyx mouth. Pods, pink brown to dark brown when mature, about 45cm long and 2cm wide; may contain up to 30 seeds embedded in a yellow pericarp. Seeds have a hard testa, are large (mean weight 0.26 g/seed) with large cotyledons forming about 70% of their weight. Robert Brown described the genus Parkia in 1826. He named it after Mungo Park, a Scot who made two remarkable journeys of exploration into the interior of West Africa, (Hopkins H.C 1983,: Sabiliti En, Cobbina J. 1992).

2.2.3 Description of Parkia filicodea

Parkia filiciodea is from the specie Parkia and family of Leguminosae. It is found in fringing forest by rivers or lakes, but sometimes it occurs in termite mounds in the West Africa region. It is a dubious tree which can grow up to 8-35 m high, crown spreading tree of medium size, its back is scaly, grey to yellow brown having young branchlets glabrous to puberulous. The leaves are petiole with the upper side usually with two narrow collateral glands; rhachis puberulous, leaflet are 10-18 pairs, oblong, often with a slight stigmoid curve, rounded at the apex, asymmetrically rounded at the base, mostly 1.2-3.2 cm long, 5-12 mm wide, glabrous except for puberulence on the margins near the base, two longitudinal nerves more distinct than the others. Parkia filiciodea has peduncle which is 9-52 cm long, with heads pendant, claviform up to 8.8 x 7.5 cm, brick red to reddish pink, with a strong pungent smell. Parkia filiciodea has bracteoles linear, enlarge at the apex, upto 15 mm long with hermaphrodite flowers; pedicel 3-4 mm long, calyx 10-14 mm long, glabrous or nearly so except for the lobes, which are densely tomemtellous outside, the larger lobes are 1.7-2.5 mm long, rounded. Its petals adnate to the staminal tube for 2-4 mm at the base, above this free for 10 mm and linear – spathulate, puberulous at the apex which is 0.6-0.75 mm wide. The pods are 30-60 cm long (including 4-10 cm long stipe), 1.5-2.8 (3.5) cm wide, glaborous or nearly so; which are margin straight or constricted between seeds (Hopkins H.C. 1983).

2.3 GROWING HABIT OF LOCUST BEAN

2.3.1 Environmental Requirement of Locust Bean

African locust bean is à light loving tree. It requires deep well drained soil and can withstand drought reasonably well once it is firmly rooted.

2.3.2 Climatic Condition

Africa locust bean is found through several climatic zones. However, it is less widely distributed in the drier northern parts of the savanna region and at the southern boundary of the Sahel in Niger and Nigeria. It occurs principally in areas with mean annual rainfall of 600mm-1400mm. The whole range of Africa locust bean experience 2-7 months main dry season, being those with rainfall (Hopkins and White, 1984).

2.4 Seed Preparation, Planting and Harvesting.

The seed needed for planting should be collected from freshly falling pods from strong and healthy trees. Viability is short, so it is best to plant the seeds as soon as possible (Dupriez, 1992). The seed is raised in a nursery and transported to the field as direct sowing of seeds shows poor germination rate. Two seeds per hole at 5m by 5m spacing, followed by thinning within 8 to 10 years after planting, (Hopkins, 1986). It is a naturally occurring tree plant as it is still in a wild state in unselected population that can be presumed to exhibit wide natural variability. It was not cultivated in the past; however, it is cultivated nowadays due to its multipurpose uses. Success with direct planting on the field has not been encouraging and surviving rates have been poor, (Busson, 1987). The first commercial fruits can be harvested after about 5-7years of planting. The pods take about 6-8 months to mature, turning from green to chocolate brown in dry season. The matured pods can be harvested by knocking them off with long poles, preferably aimed at the pods (Ikenebomeh and Kol, 1999). Direct tree climbing by men (Busson, 1987). Direct picking of pods as a result of fruit distributed by nature (wind) or animal in which have dropped to the ground and using of a curve iron which resembles a sickle.

2.5 PEST AND DISEASE

Relative pests and diseases have been identified to attack locust bean. However, the wood can be attacked by fungus which results in decolouration. No major disease or pest affects locust bean in Nigeria except sporadic attacks by leaf sucking bugs on young terminal leaves on matured trees. The seedling may be damaged by insects, small rodents or livestock but they survive easily because the damaged leaves are replaced quickly. Attack by beetles and wood borers may be prevented or reduced by gum exuded from the pods and seeds in response to the wound, (Alabi, 1993).

2.6 PROCESSING OF LOCUST BEAN

There are steps involved in the processing of locust bean. Each stage is important and must be properly done to bring out good fermented product. As at today in Nigeria, locust bean is processed locally which is crude and unhygienic. The Forestry Research Institute of Nigeria (FRIN) Ibadan has an improved method which is neater and better than the local method, prolonged time of cooking is reduced and impurities are reduced too. Processing of locust bean starts immediately after harvesting i.e. starts from the shelling of the pods and ends after the packaging of the fermented products.

2.6.1 Traditional Method of Processing of Locust Bean

The pods are split open by hand from the rear to the top after which the seeds inside the pod are removed by hand. Another way of shelling the pod is by packing them inside a jute bag after which the bag is tightened with a rope. A long stick or metal rod is used to hit the bag. After thorough hitting, the bag is opened and the seeds with the pulp are collected while the pod cases are separated. The dehulled seeds are washed in water and left to dry in the sun. It is later collected and soaked in water for 10 minutes after which they are transferred into a mortal. Fine sand is added to aid the removal of the pulp. After pounding, the locust bean seeds are collected for washing and the sand is sieved away, leaving the clean seeds. The seeds are then cooked for about 10-12 hours depending on the intensity of heat applied. Once the seed testa softens and splits up, cooking is stopped. The seeds are then moved into a mortal to dehull the seeds from the testa. After this, both the seeds and the removed testas are washed in a sieve to get rid of the testa. To ensure the proper removal of the testa, hand picking is employed. The locust bean is then parboiled for 30-60minutes with NaCl (table salt), collected and parboiled again for 20minutes. The first parboiling gives us the unmarshy type (iru - woro in Yoruba) while the second parboiling results in the marshy type (iru -pete in Yoruba).

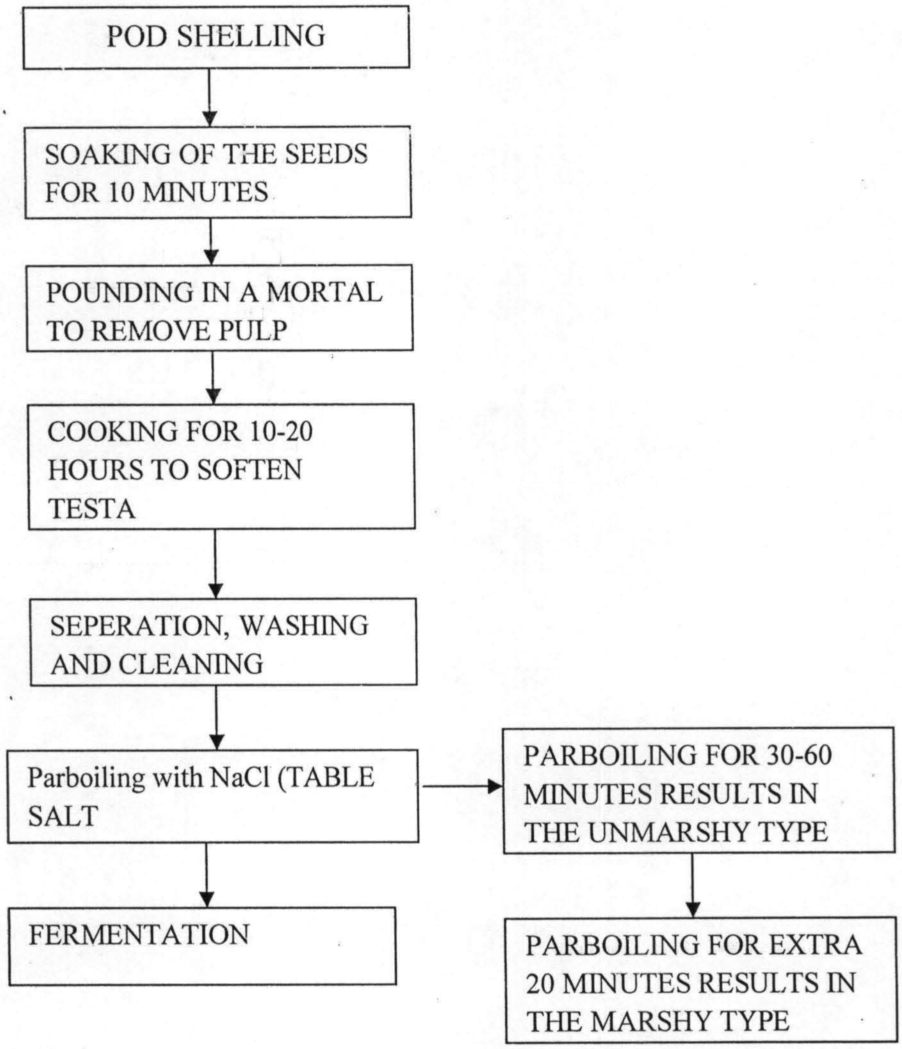


FIGURE 2.1: Flow Diagram of the Traditional Processing Method

Source (Achi 2005)

2.6.2 Ideal Standard Method

In thin method, much of the processes in the traditional method take place too, only that instead of steaming the seeds are soaked in water for 2 days and cooking is done for three hours. The seeds are then left for two or three days to ferment .

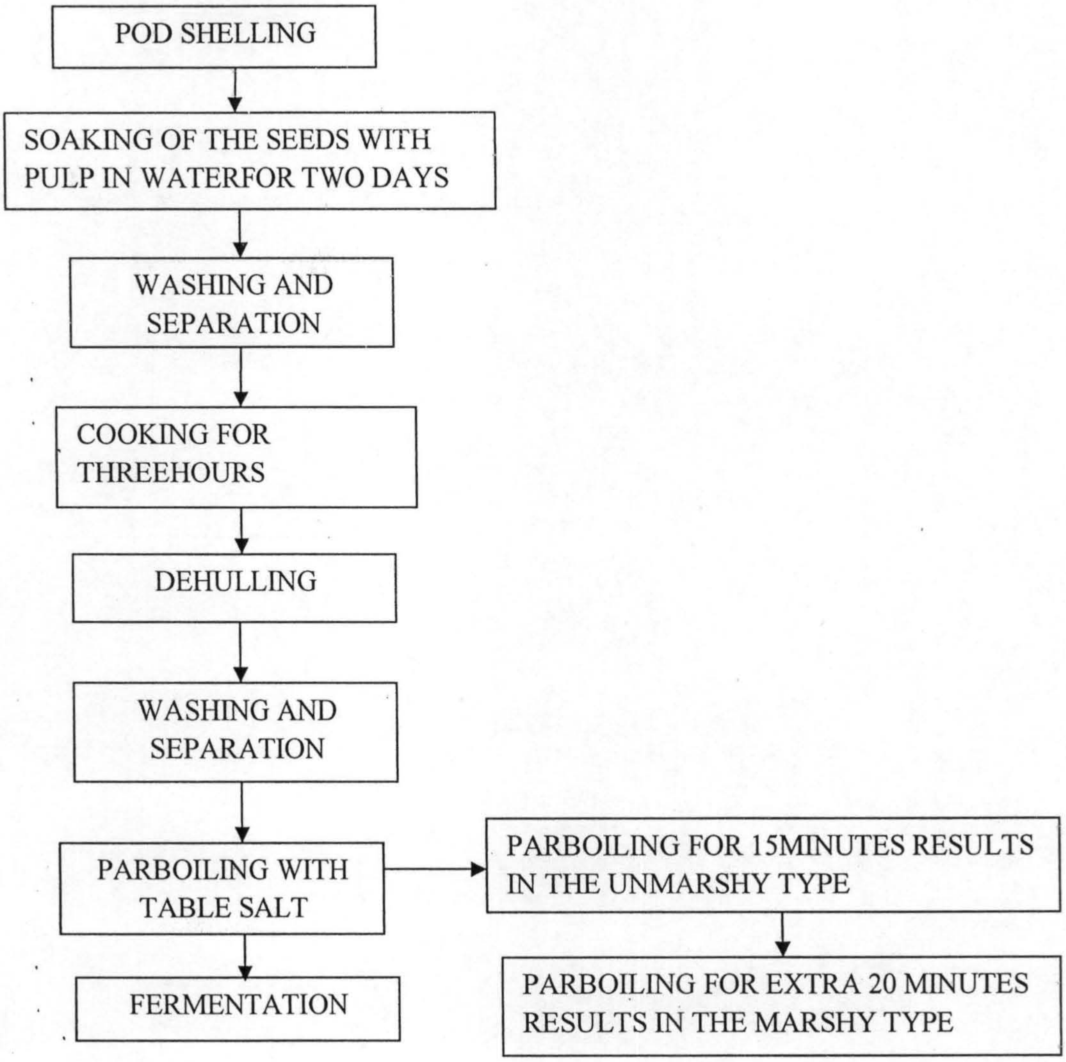


Figure 2.2: The Flow Diagram of the Ideal Standard Method

Source; (Achi, 2005)

2.7 USES OF LOCUST BEAN

The locust bean seed is a great source of medicinal resources. The leaves and the bark are used in remedies for treating guinea worm, filiariasis, skin infections and burns (Dupriez, 1992). Locust bean contribute significantly to the intake of protein, essential amino acids and vitamin B particularly riboflavin (Fetuga et al, 1973). The tree of locust bean is used as timber for making pestles, mortars, bowls and hoe handles. They are a valuable source of food especially the seeds which serve as source of useful ingredients for consumption (Campbell – Platt, 1980).

2.8 PHYSICAL PROPERTIES OF LOCUST BEAN

Physical properties are those characteristics of agricultural products that are affected by a change in the moisture content of the agricultural products. The physical properties of locust bean to be considered include:

2.8.1 Shape

This is defined as the form of which the agricultural products take with respect to standard shapes. The knowledge of the shape of agricultural products is vital in the construction and fabrication of processing machines and equipments. Shape is also important in heat and mass transfer calculations, screening solids to separate foreign materials, grading of fruits and vegetables, and evaluating the quality of food materials.

Table 2.1 Shows some standard shapes and their description.

Shapes	*Description*
Round	Approaching spheroid.
Oblate	Flatten at the stern end in shape.
Oblong	Vertical diameter greater than the horizontal diameter.
Conic	Tapered towards the peak.
Ovate	Egg shaped and broad at the stern end.
Elliptical	Approaching ellipsoid.
Truncate	Having both end squared or flattened.
Unequal	One half higher than the other.
Regular	Horizontal section approaches a circle.
Irregular	Horizontal section departs materially from a circle.

Source: Mohsenin, 1970

2.8.2 Size

Size is an important physical attribute of foods used in screening solids to separate foreign materials, grading of fruits and vegetables, and evaluating the quality of food materials. In fluid flow, and heat and mass transfer calculations, it is necessary to know the size of the sample. Size of the particulate foods is also critical. It is easy to specify size for regular particles, but for irregular particles the term size must be arbitrarily specified. Particle sizes are expressed in different units depending on the size range involved. Coarse particles are measured in millimeters, fine particles in terms of screen size, and very fine particles in micrometers or nanometers. Ultrafine particles are sometimes described in terms of their surface area per unit mass, usually in square meters per gram (McCabe *et al.*, 1993).

Size can be determined using the projected area method. In this method, three characteristic dimensions are defined:

1. Major diameter, which is the longest dimension of the maximum projected area;
2. Intermediate diameter, which is the minimum diameter of the maximum projected area or the maximum diameter of the minimum projected area; and
3. Minor diameter, which is the shortest dimension of the minimum projected area

Length (L), width (W), and thickness (T) terms are commonly used and they correspond to major, intermediate, and minor diameters, respectively. The dimensions can be measured using a micrometer or vernier caliper. The micrometer is a simple instrument used to measure distances between surfaces. Most micrometers have a frame, anvil, spindle, sleeve, thimble, and ratchet stop. They are used to measure the outside diameters, inside diameters, the distance between parallel surfaces, and the depth of holes.

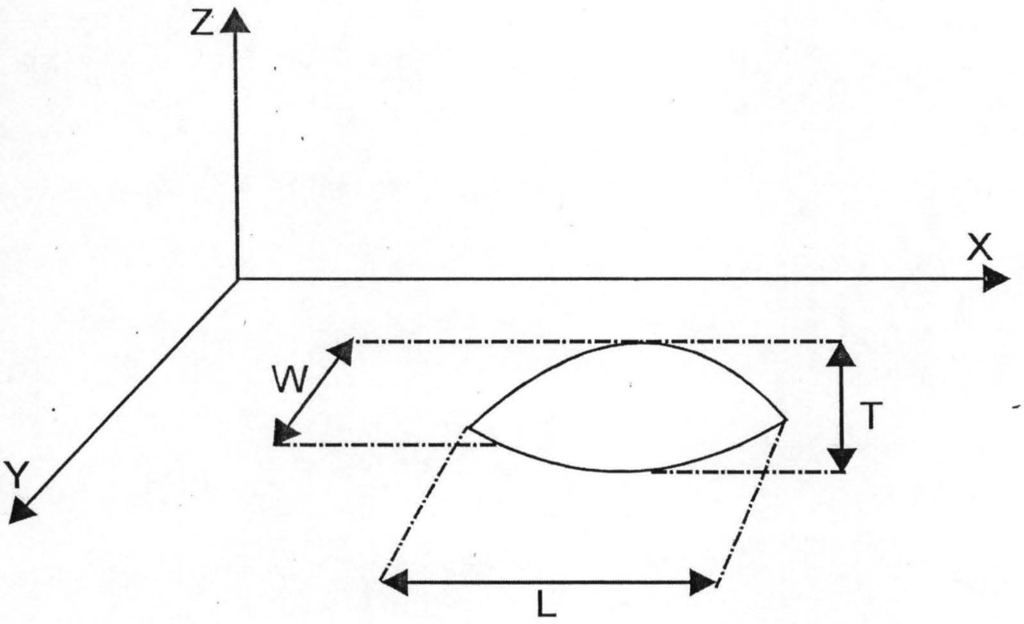


Figure 2.3 Shows the representation of the three axes and the three perpendicular dimensions of a locust bean seed.

Axial dimension in terms of major diameter (D_1), intermediate diameter (D_2), and minor diameter (D_3), which their means, can be used to evaluate arithmetic mean diameter (AMD), the geometric mean diameter (GMD), square mean diameter (SMD), equivalent diameter (EQD), the sphericity (Sc) and the aspect ratio (AR) of the samples using the equations (Mohsenin, 1986; Ciro, 1997; Eke, *et al.*, 2007).

$$\text{AMD} = \text{A} = \frac{1}{3}[D_1 + D_2 + D_3] \quad (2.1)$$

$$\text{GMD} = \text{B} = [D_1 \times D_2 \times D_3]^{1/3} \quad (2.2)$$

$$\text{SMD} = \text{C} = \sqrt{\frac{D_1D_2 + D_2D_3 + D_3D_1}{3}} \quad (2.3)$$

$$\text{EQD} = \frac{A + B + C}{3} \qquad (2.4)$$

$$\text{Sc} = \frac{GMD}{D_1} \qquad (2.5)$$

$$\text{AR} = \frac{D_2}{D_1} \qquad (2.6)$$

2.8.3 Colour

Colour is one of the important quality attributes in foods. Although it does not necessarily reflect nutritional, flavour, or functional values, it determines the acceptability of a product by consumers. It may be desirable to follow the changes in colour of a product during storage, maturation, processing, and so forth. Colour is often used to determine the ripeness of fruits. Colour is a perceptual phenomenon that depends on the observer and the conditions in which the colour is observed. It is a characteristic of light, which is measurable in terms of intensity and wavelength. Colour of a material becomes visible only when light from a luminous object or source illuminates or strikes the surface. Colour can be measured using a colorimeter or even using the natural white light. Surface colour and appearance are valuable physical properties for selective separation in the field as subsequent handling and processing.

2.8.4 Volume and Density

Volume is defined as the amount of three-dimensional space occupied by an object, usually expressed in units that are the cubes of length units, such as cubic inches and cubic centimeters, or in units of liquid measure, such as gallons and liters. In the SI system, the unit of volume is m^3. Volume is an important quality attribute in the food industry. It appeals to the eye, and is related to other quality parameters. For instance, it is inversely correlated with texture.

Volume of solids can be determined by using the following methods:

1. Volume can be calculated from the characteristic dimensions in the case of objects with regular shape.
2. Volumes of solid can be determined experimentally by liquid, gas, or solid displacement methods.
3. Volume can be measured by image processing method. An image processing method has been recently developed to measure volume of ellipsoidal agricultural products such as eggs, lemons, limes, and peaches.

Quality of food materials can be assessed by measuring their densities. Density data of foods are required in separation processes, such as centrifugation and sedimentation and in pneumatic and hydraulic transport of powders and particulates. In addition, measuring the density of liquid is required to determine the power required for pumping. It is also an important physical property to be considered in the fabrication of processing machinery. Density can be calculated after measuring the mass and volume of the object because it is defined as the mass per unit volume. In the S.I. system, the unit of density is kg/m^3.

2.8.5 Weight

In handling and processing of agricultural produce, the weight of the produce plays an important role such that it should be critically considered by agriculturalist and engineers. This is the effect of the earth's gravitational force on the mass of agricultural produce. It is usually expressed as the product of the mass (kg) and the constant of the earth's gravitational pull (m/s^2). Its SI unit is Newton (N) and it is mathematically expressed as:

$$w = mg \qquad (2.7)$$

where;

w = Weight

m = Mass

g = Acceleration due to gravity

2.8.6 Porosity

Porosity is a measure of the void spaces in a material, and is a fraction of the volume of voids over the total volume, which could be between 0 to 1 or as a percentage between 0 to 100%. The term is used in multiple fields including pharmaceutics, ceramics, metallurgy, materials, manufacturing, earth sciences, and construction. Porosity is an important physical property characterizing the texture and the quality of dry and intermediate moisture foods. Porosity data is required in modeling and design of various heat and mass transfer processes such as drying, frying, baking, heating, cooling, and extrusion. It is an important parameter in predicting diffusion properties of cellular foods. A value for porosity can alternatively be calculated from the bulk density and particle density. (Mohsenin, 1970; Fathollahzadeh *et al.,* 2008):

$$P_f = \left[1 - \frac{\rho_b}{\rho_p}\right] \times 100 \qquad (2.8)$$

2.8.7 Surface Area

This is the total surface area of an agricultural product, that is, the area covered by the peels, coatings etc. of an agricultural product when spread out. Knowledge of surface area of some parts of plant materials such as leaf area and surface area of fruits is important to plants scientists as well as agricultural engineers in handling and processing of agricultural products. Some applications of measurement of plant leaves is to determine the rate of insecticide and fungicide application rate, plant competition for light and nutrient, plant-soil-water relationship and leaf area is an indicator of yield potential. Mohsenin (1980) summarized the current method for measuring surface area of various biomaterials. For example, to find the surface area of leaves, one can trace it on tracing paper and surface area is then determined by a planimeter. In the absence of a planimeter, one could trace the peels on a graph paper and find the area by counting squares.

2.8.8 Angle of Repose

Angle of repose is the angle with the horizontal at which a material will stand when piled. This is also defined as the angle subtended at the centre when the agricultural product is allowed to freely stay in form of a heap without being bounded by any boundary or structure whatsoever, that is, it is the angle subtended at the centre when the product is in its free state. The size, shape, moisture content, and orientation of the particles have influence on the angle of repose. Frictional properties of granular materials such as seeds and grains are important in the design of equipment for solid flow and structure for storage of these materials (Mohsenin, 1986). Although engineers assume generally that the angle of repose and the angle of internal friction are approximately the same, but they are not and using one in place of the other in design can introduce errors.

There are two types of angles of repose namely;

- Static angle of repose
- Dynamic angle of repose

The static angle of repose is the angle of friction taken up by a granular solid when it is about to slide upon itself. The dynamic angle of repose is more important because it arises in all cases where the bulk of the material is in motion or the solid discharging from bins and hoppers (Mohsenin, 1986). Fowler and Wyatt (1990) measured angle of repose using a circular platform immersed in a bowl filled with the granular material or solid and with a glassy window on side. The platform was supported by adjustable screw leg and was surrounded by metal funnel leading to a discharge hole. The solid was allowed to escape from the box having a free standing cone of solids on the platform, a cathetometer (travelling micrometer) was used to measure the height. The angle of repose was calculated from the geometry of the cone as follows:

$$\theta_r = \tan^{-1}\frac{2(H_p - H_c)}{D_p} \tag{2.9}$$

where:

θ_r =Angle of repose, deg.

H_p = Height of platform, mm

H_c = Height of cone, mm

D_p = Diameter of platform, mm

Also the angle of repose can be found using the relationship (Kaleemullah, 1992)

$$\theta_r = \tan^{-1}\frac{2(H)}{D} \qquad (2.10)$$

where:

θ_r =Angle of repose, deg.

H = Height above the floor, mm

D = Diameter of the heap at its base, mm

2.8.9 Coefficient of Friction

The coefficient of static friction is between one surface and another in the form of plane, is to place the body on the plane and gradually to increase the angle of inclination of the plane until the body is just to slide down the plane. It can be done on several surfaces (wood, metal, glass and asbestos). The static and dynamic of grains, forage and some other agricultural product on metals, wood and other materials are needed by design engineers for rational design and predicting motion of the material in harvesting and handling equipments. Coefficient of friction is also important in determining the pressure of grain and silage against bin walls and silo.

2.9 MOISTURE CONTENT

The moisture content of a produce simply indicate the amount of water present in that agricultural produce and this, is of great importance to both food scientist and agricultural engineers as it helps in determining certain adaptation and resistance to processing stages such as drying, bagging, storage, cooking, and even consumption. It can be expressed in dry or wet basis.

$$M_c = \frac{W_i - W_f}{W_i} \times 100 \qquad (2.11)$$

where:

M_c = Moisture content, % dry basis

W_i = initial weight of sample, kg

W_f = final weight of sample, kg

2.10 MECHANICAL PROPERTIES OF LOCUST BEAN

These properties are those that have to do with the behavior of agricultural products under applied forces. According to (Anazodo1983) knowledge of mechanical properties of agricultural products (such as compressive and tensile strengths) under static or dynamic loading is aimed at textural measurement of unprocessed and processed food material; the reduction of mechanical damage to agricultural produce during handling, processing, and storage; and the determination of design parameters for harvest and post harvest systems.

2.10.1 Compressive Strength

Maximum stress a material can sustain under crush loading. The compressive strength of a material that fails by shattering fracture can be defined within fairly narrow limits as an independent property. However, the compressive strength of materials that do not shatter in compression must be defined as the amount of stress required to distort the material an arbitrary amount. Compressive strength is calculated by dividing the maximum load by the original cross-sectional area of a specimen in a compression test.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 SELECTION OF MATERIALS

Locust bean (Parkia biglobosa) seeds used for investigation were obtained from two agro-ecological regions of Nigeria. The regions are the Southern Guinea Savvanna region where Kogi and Niger state seeds were considered and the tropical high rain forest region where Oyo state was considered. Three mudus of the seeds was obtained from each state. Plate 3.1 to 3.3 shows the samples from the three states.

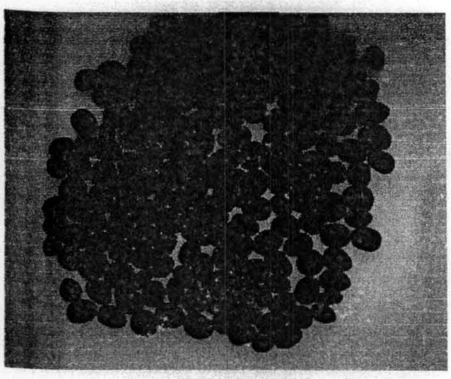


Plate 3.1 sample from Kogi state

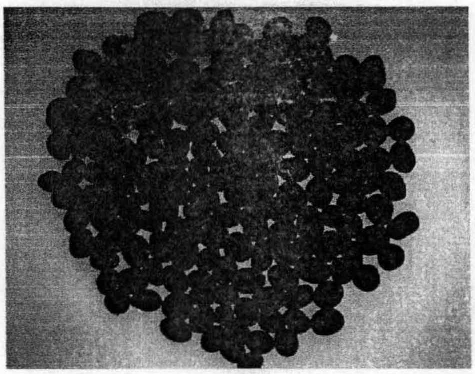


plate 3.2 sample from Niger state

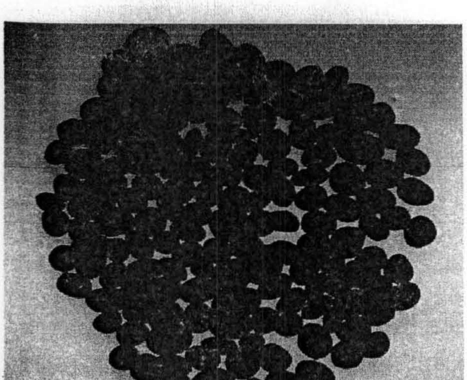


Plate 3.3 sample from Oyo state

3.2 PREPARATION OF THE MATERIALS

The samples were cleaned to remove foreign matter, dust, dirt, broken and immature seeds, by winnowing and hand picking. The Samples were carefully selected to ensure that only good seeds were used so as to eliminate getting incorrect results.

3.3 MOISTURE CONTENT DETERMINATION

Moisture content of the samples was determined using the procedure detailed by Henderson *et al*, (1997). The samples were dried at 130°C for 18 hours. The weight loss of the samples was recorded and the moisture determined in percentage. The moisture content was calculated using equation 2.11.

3.4 DETERMINATION OF THE PHYSICAL PROPERTIES

3.4.1 Shape Determination

Ten (10) seeds of each from the three samples were wrapped in foil paper. The boundaries were traced on the cardboard and then compared with the charted standards given in table 2.1, and the closest shape was designated for each of the materials under investigation.

3.4.2 Size Determination

Thirty (30) seed were selected at random and numbered 1 to 30, for seeds in the three samples. Axial dimension in terms of major diameter (D_1), intermediate diameter (D_2), and minor diameter (D_3) were measured using a vernier caliper with reading to 0.01 mm precision. While D_1, D_2 and D_3 were used to evaluate arithmetic mean diameter (AMD), the geometric mean diameter (GMD), square mean diameter (SMD), equivalent diameter (EQD), the sphericity (Sc) and the aspect ratio (AR) of the materials under investigation using equations 2.1 to 2.6 respectively.

3.4.3 Colour Determination

The colour is that part of white light that is reflected when light falls on them. It can be measured using a colorimeter or even using the natural white light. The colours of the samples were obtained with the use of natural sunlight viewed in well lit, visible environment.

3.4.4 Determination of1000 Seed Weight

A thousand seed weight was measured by counting 100 seeds and weighing them in an electronic balance to an accuracy of 0.001g (Ohaus adventurer) and then multiplying it by 10 to give mass of 1000 seeds. Three replicate were obtained for the three samples of Parkia biglobosa.

3.4.5 Measurement of Volume

The volume of individual seed was measured using the water displacement method. Each weighed sample was tied to a sinker of known weight lowered into the cylinder with water and volume of water displaced in a measuring cylinder was read off as the volume of the seed. Due to the short duration of experiment, the seeds were not coated to prevent moisture adsorption since it did not result in a significant increase in weight as reported by Olajide and Ade-Omowaye (1999). (Asoegwu *et al*, 2006). Three replicate of the samples were obtained.

3.4.6 Determination of Particle Density

The particle density was defined as the ratio between the mass of seeds and the true volume of the seeds, and determined using toluene (C_7H_8) displacement method. Toluene was used instead of water because it is less absorbed by seeds. The volume of toluene displaced was found by immersing a weighted quantity of seeds in the measured toluene (Mahmoud *et al,* 2009). The samples were replicated three times and the averages calculated for each of the three samples of Parkia biglobosa, then the true density calculated using this equation.

$\rho_t = \frac{M}{V_t}$ Ayman *et al,* (2010) Where $V_t$the real volume of bulk seeds ism^3, ρ_t is the true density in kg/m^3 and M is the weight of the bulk seeds kg.

3.4.7 Determination of Bulk Density

The bulk density, of the samples was determined using a container of known volume. The container was filled to the brim with the samples. The sample was densely packed by gently tapping the container 10 times in the same manner for all measurements to allow the seeds to settle in the container (Waziri and Mittal, 1983) so as to obtain uniform density. The samples which filled the container respectively, was weighed using electronic mettler balance (Ohaus adventurer) as shown on plate 3.4. The volume of the container was estimated. Three replicate of the bulk density were obtained. The bulk density of sample was calculated as the ratio of the bulk weight and the volume of the container.

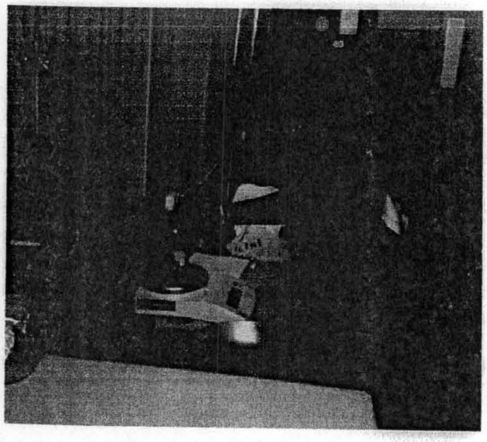


Plate 3.4 determination of bulk density

3.4.8 Determination of Porosity

Porosity (P_f) of the bulk seed was computed from the values of the true density and bulk density of the seeds by using the relationship shown in equation 2.8.

3.4.9 Determination of Surface Area

Aluminium foil was used to wrap the locust bean seeds for the three samples and well trimmed to take the shape of the seed. The foil was thereafter removed and with the aid of a graph paper the surface area was measured (Ayman *et al,* 2010). The procedure was replicated three times for the three samples and the average values taken to represent the measured surface areas of Parkia biglobosa.

3.4.10 Determination of Angle of Repose

Some quantities from each of the three samples were used to determine angle of repose of the locust bean seeds. The seeds were poured under gravity to form a cone at the same spot. More seeds were let to be fallen on the top of the formed cone until the angle between the cone surface and the horizontal plane became constant as shown in plate 3.6. The angle between the cone surface and the horizontal plan was recorded to represent angle of repose of the seeds. The recorded angle was the average of the three replicates.

3.4.11Determination of Coefficient of Friction

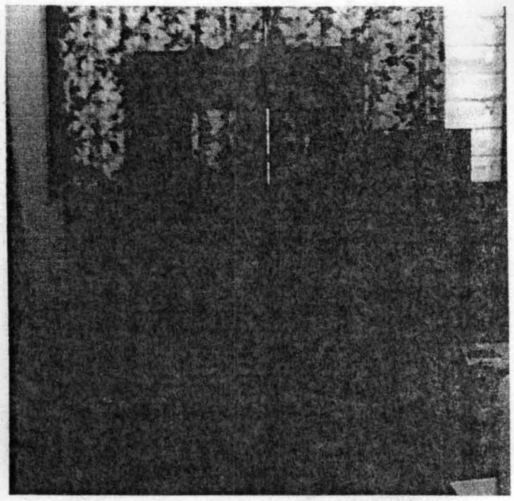
The coefficient of static friction of the seed was determined against three structural materials: glass, plywood and metal. A wooden box measuring 450mmx450mm was constructed without a base (Olajide et al, 2000) and placed on an adjustable tilting plate faced the test surface. There were two pieces of plastic between the box and the plate placed under the sides of the walls of the box oppositely to raise the box up and not to touch the plate surface. Then the box was filled with the samples, the two pieces of plastic removed which made the box to remain above the plate but the samples touched the plate. The inclination of the plate was increased gradually by a screw device until the box just starts to slide down. The angle of tilt Ø in degree was read from a graduated scale. This was done three times and the coefficient of static friction μ calculated from the expression (Shephard and Bhardwaj 1986) below:

$\mu = \tan \phi$

3.5 DETERMINATION OF THE MECHANICAL PROPERTY

3.5.1 Compressive Strength

The machine used is the universal testing machine manufactured by the micro vision industry (model number 4026538MV) as shown in plate 3.5. This machine is software driven; manual operations are involved only when loading and unloading of a product. First the dimensions of the samples were taken for each of the three samples of Parkia biglobosa. The platens for compression testing are fixed in position. The stationary platen at the bottom, the movable platen is attached to the arm that applies the pressure. Pressure is applied by the upper arm pressing down on the product which is placed centrally on the bottom platen, which remains stationary. Sensors attached to the load cells of the machine measure the variations in pressure applied on the product and the dimensions of the product till it fails. All details are saved in the computer system that has been interfaced with the machine



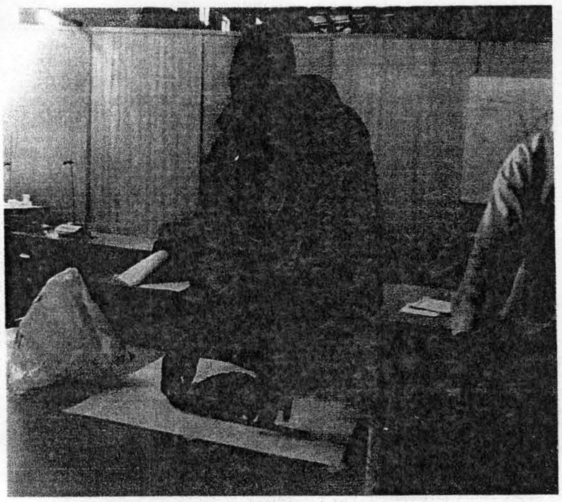


Plate 3.5Universal testing machine **Plate 3.6 Determining angle of repose**

3.6 STATISTICAL ANALYSIS.

Triplicates of each sample were obtained during the experiment. The tool used for computation and comparison are mean, standard deviation, using Microsoft Excel 2007 and ANOVA at 95% confidence level

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 PRESENTATION OF RESULTS ON PHYSICAL PROPERTIES

4.1.1 Moisture Content

The results of the experiments are presented in tables 4.1 to 4.7 and at predetermined moisture contents for the samples used. The moisture contents for the Parkia biglobosa samples are shown below;

Table 4.1: Moisture Contents for the Parkia biglobosa Samples

S/No	Parkia biglobosa Samples	Moisture Content, %
1.	KOGI seeds	12.02
2.	NIGER seeds	10.53
3.	OYO seeds	9.72

The moisture content is of great importance to food scientists and processing engineers as it assists them to determine certain adaptation and resistance to processing stages such as drying, bagging, storage, cooking and even consumption.

4.1.2 Shape and Colour

The traced boundary outlines of the samples were compared with charted standard in table 2.1. The shape of samples from Kogi and Niger state is flat and spherical, while that of sample from Oyo state is almost round. The colour of sample from Kogi state is black, Sample from Niger state is black and dark brown and sample from Oyo state is dark and reddish brown which are subjective properties.

4.1.3 Measured parameters

The means, standard deviations and coefficient of variation of the measured values of major diameter D1, intermediate diameter D2, minor diameter D3, 1000 seed weight and volume (V) of the three samples of Parkia biglobosa seeds a are presented in tables 4.2 to 4.4.

Table 4.2: Means and standard deviation of measured parameters of sample from Kogi state

Measured Parameters	Unit	Maximum Value	Minimum Value	Mean	Standard deviation
Major Diameter	Mm	0.99	0.75	0.87	0.12
Intermediate Diameter	Mm	0.75	0.56	0.655	0.095
Minor Diameter	Mm	0.33	0.21	0.27	0.06
1000 Seed Weight	g/1000seed	220.5	216.2	218.4	2.15
Volume (V_{1000})	cm^3	55.1	54.66	54.88	0.22

Table 4.3: Means and standard deviation of measured parameters of sample from Niger state

Measured Parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation
Major Diameter	Mm	0.88	0.66	0.77	0.11
Intermediate Diameter	Mm	0.71	0.43	0.57	0.14
Minor Diameter	Mm	0.33	0.21	0.27	0.06
1000 Seed Weight	g/1000seed	211	210.7	210.9	0.15
Volume (V1000)	cm^3	56.12	55.33	55.73	0.395

Table 4.4: Means and standard deviation of measured parameters of sample from Oyo state

Measured Parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation
Major Diameter	Mm	0.84	0.61	0.725	0.115
Intermediate Diameter	Mm	0.72	0.49	0.605	0.115
Minor Diameter	Mm	0.36	0.15	0.255	0.105
1000 Seed Weight	g/1000seed	200.1	194.5	197.3	2.8
Volume (V_{1000})	cm^3	55	54	54.5	0.5

4.1.4 Calculated Parameters

The means and standard deviations of the calculated values are shown below in tables 4.5 to 4.7.

Table 4.5: Means and standard deviation of some physical properties (calculated) sample from Kogi state.

S/No	Calculated Parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation
1	Arithmetic Mean Diameter	Mm	0.637	0.543	0.590	0.047
2	Geometric Mean Diameter	Mm	0.064	0.039	0.052	0.012
3	Square Mean Diameter	Mm	0.606	0.524	0.565	0.041
4	Equivalent Diameter	Mm	0.637	0.534	0.586	0.051
4	Equivalent Diameter	Mm	0.637	0.534	0.5855	0.051
5	Sphericity	Dec	0.076	0.049	0.062	0.013
6	Aspect Ratio	Dec	0.910	0.626	0.768	0.142
7	Particle Density	g/cm^3	0.872	0.816	0.844	0.028
8	Bulk Density	g/cm^3	0.780	0.780	0.780	0.000
9	Porosity	%	10.540	4.380	7.460	3.080
10	Surface Area	cm^2	3.160	3.000	3.080	0.080
11	Angle of Repose	Deg	20.270	19.200	19.735	0.535
12	Coefficient of friction					
	Glass	Deg	0.488	0.404	0.446	0.042
	Plywood	Deg	0.532	0.445	0.488	0.043
	Galvanized steel sheet	Deg	0.445	0.364	0.405	0.041

Table 4.6: Means and standard deviation of some physical properties (calculated) of sample from Niger state

S/No	Calculated Parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation
1	Arithmetic Mean Diameter	Mm	0.570	0.477	0.523	0.047
2	Geometric Mean Diameter	Mm	0.051	0.031	0.041	0.010
3	Square Mean Diameter	Mm	0.555	0.463	0.509	0.046
4	Equivalent Diameter	Mm	0.477	0.570	0.523	0.047
5	Sphericity	Dec	0.072	0.048	0.060	0.012
6	Aspect Ratio	Dec	1.000	0.623	0.812	0.188
7	Particle Density	g/cm^3	0.825	0.816	0.821	0.005
8	Bulk Density	g/cm^3	0.809	0.808	0.808	0.000
9	Porosity	Dec	2.060	0.900	1.480	0.580
10	Surface Area	cm^2	2.680	2.560	2.620	0.060
11	Angle of Repose	Deg	21.210	19.320	20.265	0.945
12	Coefficient of friction					
	Glass	Deg	0.384	0.364	0.374	0.010
	Plywood	Deg	0.445	0.425	0.435	0.010
	Galvanized steel sheet	Deg	0.445	0.384	0.415	0.031

Table 4.7: Means and standard deviation of some physical properties (calculated) of sample from Oyo state

S/No	Calculated Parameters	Unit	Maximum Value	Minimum Value	Mean	Standard Deviation
1	Arithmetic Mean Diameter	Mm	0.587	0.477	0.532	0.055
2	Geometric Mean Diameter	Mm	0.054	0.027	0.041	0.014
3	Square Mean Diameter	Mm	0.560	0.456	0.508	0.052
4	Equivalent Diameter	Mm	0.473	0.587	0.530	0.057
5	Sphericity	Deg	0.076	0.040	0.058	0.018
6	Aspect Ratio	Deg	1.000	0.431	0.715	0.285
7	Particle Density	g/cm^3	0.913	0.912	0.913	0.001
8	Bulk Density	g/cm^3	0.857	0.837	0.847	0.010
9	Porosity	Deg	8.310	6.040	7.175	1.135
10 .	Surface Area	Cm^2	2.560	1.920	2.240	0.320
11	Angle of Repose	Deg	21.390	21.100	21.245	0.145
12	Coefficient of friction					
	Glass	Deg	0.425	0.364	0.394	0.030
	Plywood	Deg	0.425	0.364	0.394	0.030
	Galvanized steel sheet	Deg	0.404	0.306	0.355	0.049

Table 4.8 statistical analysis using ANOVA

S/N	Parameters	Degree of freedom	Calculated F distribution	Tabular F distribution	Remarks
1	Moisture content	8	6.125	5.14	S
2	Major diameter	8	7.740	5.14	S
3	Intermediate diameter	8	3.255	5.14	NS
4	Minor diameter	8	216.00	5.14	S
5	Seed weight	8	5.148E4	5.14	N
6	Volume of seed	8	0.882	5.14	NS
7	Particle density	8	2.839E3	5.14	NS
8	Bulk density	8	14.020	5.14	S
9	Porosity	8	1.014E6	5.14	NS
10	Surface area	8	159.224	5.14	S
11	Angle of repose	8	1.104E5	5.14	NS
12	CEFG	8	6.216E3	5.14	S
13	CEPS	8	1.999E4	5.14	NS
14	CEFS	8	4.650E3	5.14	NS
15	Compressive strength	8	20.686	5.14	S

4.1.5 Discussion of Result on Physical Properties

It was observed from Tables 4.2 to 4.7 that the length (D1), width (D2), and thickness (D3) for sample from Kogi state, sample from Niger state, and sample from Oyo state have mean values of 0.87 ± 0.12, 0.655 ± 0.095, 0.27 ± 0.06; 0.77 ± 0.11, 0.57 ± 0.14, 0.27 ± 0.06; 0.725 ± 0.115, 0.605 ± 0.115, 0.225 ± 0.105 respectively. Samples from Kogi state had the highest values for the three dimensions, while samples from Oyo state had the lowest values for the three dimensions. With known axial dimensions, the product can be effectively graded. Sieves can now be designed within a range for separation of the seeds from the pulp. In the design of machine for processing, the knowledge of different dimensions is important so as to minimize wastage or breakage while grading, washing, and dehusking. The mean values of a thousand seed weight and the volume for sample from Kogi, Niger, and Oyo are 218.35 ± 2.15, 54.88 ± 0.22; 210.85 ± 0.15, 55.73 ± 0.395; 197.3 ±2.80,54.50± 0.500 respectively. Samples from Kogi state had the highest values for volume and samples from Oyo state had the lowest values. The weights of agricultural products are exploited in the design of cleaning equipment using aerodynamic forces (Ọje and Ugbor, 1991), also practical application of seed mass is in the design of equipment for separation, conveying and elevating unit operations. The high variation in seed weight may likely be attributed to presence of immature seeds, damaged or unfilled seed.

The data on tables 4.5 to 4.7 gives the means, and standard deviation of calculated values of calculated parameters of the three samples of Pakia biglobosa. For samples from Kogi state, AMD has a mean of 0.590 mm ranging from 0.5433 mm to 0.6376 mm, GMD has a mean of 0.052 mm ranging 0.0393 mm to 0.0642 mm, SMD has a mean of 0.565 mm ranging from 0.5243 mm to 0.6059 mm, ED has a mean of 0.587 mm ranging from 0.537 mm to 0.637. For samples from Niger state, the means for the AMD, GMD, SMD, and ED are 0.523 mm, 0.041 mm, 0.509 mm and 0.523 mm respectively. The AMD, GMD, SMD and ED for samples from

Oyo state are 0.532 mm, 0.041 mm, 0.530 mm and 0.530 mm respectively. AMD for samples from Kogi state had the highest value and samples from Niger state had the lowest values, GMD and SMD for samples from Niger and Oyo state were similar, but samples from Kogi had the highest values for both GMD and SMD. Samples from Kogi state had the highest values for ED while samples from Niger state had the lowest values. The arithmetic mean and geometric mean can therefore be used to determine the average diameter of Parkia biglobosa. This is useful in determining the diameter of sieve hole.

Sphericity and aspect ratio ranged from 0.0491 to 0.0758and 0.6263to 0.9103and mean values of 0.062and 0.768respectively for samples from Kogi state. For samples from Niger state, sphericity ranged from 0.0441 to 0.0723 with mean value of 0.0600 and aspect ratio ranged from 0.6232 to 0.9859 with mean value of 0.812. Sphericity for samples from Oyo state ranged from 0.0399 to 0.0755 with mean value of 0.0580 and the aspect ratio ranged from 0.4305 to 1.0000 with mean value of 0.7150. The values for sphericity for samples from Kogi and Niger state are similar while samples from Oyo had the least value. Sphericity values of most agricultural produce have been reported to range between 0.32 and 1.00 and the more regular an object is, the lower the sphericity (Mohsenin, 1970; Irtwange and Igbeka, 2002). Low aspect ratio Eke *et al*, (2007) reported is the tendency to being oblong in shape. However, with an aspect ratio of over 70%, the three samples of Parkia biglobosa is more likely to roll than to slide. This is important information for hopper, separation and conveying equipment design.

The particle density and the bulk density for samples from Kogi state ranged from 0.81806 g/cm^3 to 0.87167 g/cm^3 with a mean value of 0.84400 g/cm^3 and 0.7798 g/cm^3 to 0.7802 g/cm^3 with a mean value of 0.7800 g/cm^3 respectively. For samples from Niger state, particle density has a mean value of 0.8210 g/cm^3 and the bulk density has a mean value of 0.8080 g/cm^3. For samples from Oyo state has particle density with a mean value of 0.9130 g/cm^3 while the mean value for the bulk density is 0.8470 g/cm^3. The particle density and bulk density differs for the three samples and the bulk density was lesser than the particle density for the three samples. The particle density of agricultural products have been reported to play significant importance in the design of silos and storage bins, maturity and quality evaluation of products which are essential to grain marketing (Irtwange and Igbeka,2002). Bulk density has also been reported to have practical applications in the calculation of thermal properties in heat transfer problems, in determining Reynolds number in pneumatic and hydraulic handling of materials and in predicting physical structure and chemical composition (Irtwange and Igbeka, 2002). The mean values for porosity for samples from Kogi, Niger, Oyo state are 7.4600, 1.4800, and 7.175 respectively. The porosity for sample from Niger state had the lowest porosity while porosity for samples from Kogi and Oyo state are similar. The surface area for sample from Kogi state is greater with mean valve of 3.080cm^2 than samples from Niger and Oyo state with man valves of 2.620cm^2 and 2.240cm^2 respectively. The sample from Kogi state had the largest surface area while sample from Oyo state had the least surface area. The surface area is a relevant tool in determining the shape of the seeds. This will actually be an indication of the way the splits will behave on oscillating surfaces during processing (Alonge& Adigun, 1999).

The sample from Oyo state has the highest mean value of angle of repose with 21.245°, followed by samples from Niger state with mean value of 20.265°, and the least is sample from Kogi state with the mean value of 19.735°.The angle of repose is important for the design of processing, storage, and conveying systems of particulate material. When materials are smooth and rounded, the angle of repose is low. For very fine and sticky materials the angle of repose is high. The angle of repose of any of the samples can be used in the design of processing and handling equipment. Also, this phenomenon is imperative in the food processing, particularly in the designing of the hopper.

Samples from Kogi and Niger state has the highest coefficient of friction on plywood with mean values of 0.488° and 0.435° respectively, while samples from Oyo state has its least coefficient of friction on galvanized steel metal with the mean value of 0.355°, and the same mean values for both glass and plywood medium which is 0.394°.

4.2 Presentation of Results on Mechanical Properties

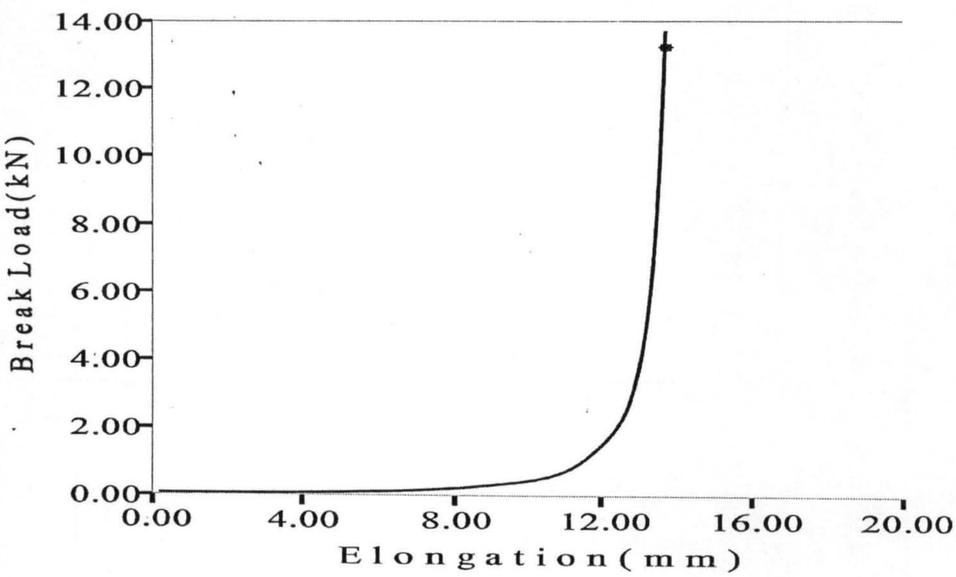


Fig. 4.1 :Break Load against Elongation (Area of 2.76 cm^2) **(Sample Kogi)**

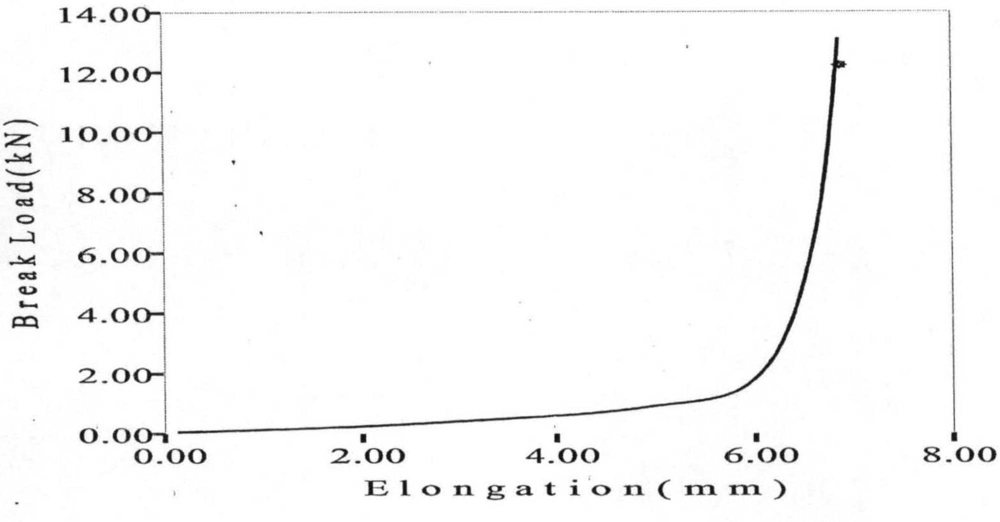


Fig. 4.2: Break Load against Elongation **Sample Niger** (Area of 1.72 cm^2)

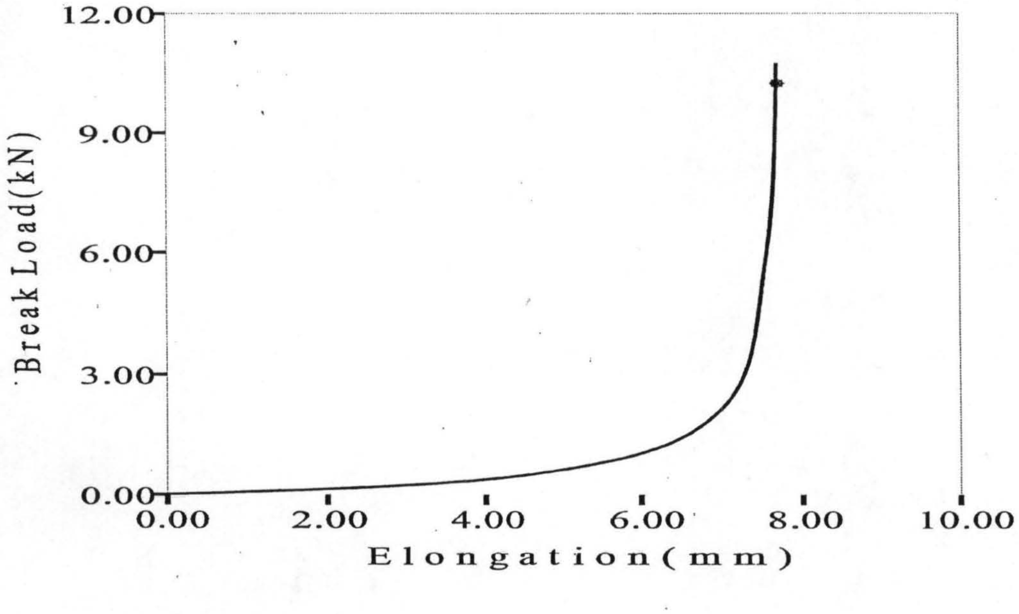


Fig. 4.3: Break Load against Elongation **Sample Oyo** (Area of 1.55 cm^2)

4.2.1 Discussion of Result on Mechanical Properties

With an anvil height of 6.59 mm set on the Universal testing machine. For samples from Kogi state, the compressive load at break is 13.09 K N at compressive elongation of 13.78 mm with an area of 2.76 cm^2, this shows that maximum elongation was attained at 13.78 mm with maximum break load of 13.09 KN. For samples from Niger state, the compressive load at break is 12.07 K N at compressive elongation of 6.87 mm with an area of 1.72 cm^2,this shows that maximum elongation was 6.87 mm at maximum break load of 12.07 KN. For sample from Oyo state, the compressive load at break is 10.11 K N, at compressive elongation of 7.73 mm with area of 1.55 cm^2, this shows that at maximum break load of 10.11 KN maximum elongation of 7.73 mm was attained. The samples from Kogi state had the highest compressive strength which is as a result of the black seed testa while sample from Oyo state has the lowest compressive strength due to the brown seed testa. The probability of fracture of a particle under tension or compression depends on the applied macroscopic stress and the size of the particle. A farm product machine designer needs knowledge of the compressive strength of Parkia biglobosa for process design and handling.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The physical and mechanical properties of Parkia biglobosa from Southern Guinea Savvanna (Kogi and Niger state) and High tropical rain forest (Oyo state) were investigated. The physical properties includes shape, size, geometric mean diameter, sphericity, colour, seed mass, volume, particle density, bulk density, porosity, surface area, angle of repose, coefficient of friction, while the mechanical property is the compressive strength. There was significant difference in the mechanical property for the seeds from the three states. These could mean that there may be difference in the energy required in the crushing of the seeds from the three states. It was also observe significant difference in some of the physical properties studied within the three states. These parameters are important in designing equipment for handling and processing operations of the product.

5.2 Recommendations

The following are recommended for further research;

1. Other engineering properties of Parkia biglobosa should be worked on to provide fairly comprehensive information in design parameters.
2. Determination of how these agro ecological zones affect the engineering properties of Parkia biglobosa should be investigated.

3. The government should establish institutions and programs that would carry out more in-depth research and utilization of the Parkia biglobosa varieties available in the tropical region of the world.
4. Determination of engineering properties of other species of African locust bean is to be encouraged.

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APPENDIX

A: Calculated Parameters for Samples from Kogi state

S/N	AMD	GMD	SMD	EQD	SC	AR
1	0.6100	0.0563	0.5848	0.6067	0.0687	0.8659
2	0.6233	0.0532	0.5866	0.6233	0.0537	0.6263
3	0.5733	0.0449	0.5495	0.5733	0.0576	0.8846
4	0.5667	0.0504	0.5520	0.5667	0.0672	0.8267
5	0.5933	0.0437	0.5596	0.5933	0.0491	0.7528
6	0.5867	0.0497	0.5669	0.5867	0.0599	0.7470
7	0.5867	0.0512	0.5644	0.5867	0.0610	0.7500
8	0.6167	0.0630	0.5974	0.5833	0.0758	0.7590
9	0.5767	0.0441	0.5503	0.5767	0.0544	0.8395
10	0.5867	0.0528	0.5675	0.5867	0.0660	0.8250
11	0.6000	0.0572	0.5819	0.6000	0.0733	0.9103
12	0.6367	0.0522	0.6030	0.6367	0.0600	0.8152
13	0.6233	0.0570	0.5960	0.6233	0.0648	0.8182
14	0.6000	0.0470	0.5699	0.6000	0.0560	0.8690
15	0.6267	0.0642	0.6059	0.6267	0.0747	0.8140
16	0.5900	0.0470	0.5635	0.5900	0.0566	0.8313
17	0.5933	0.0532	0.5724	0.5933	0.0674	0.8395
18	0.5900	0.0546	0.5746	0.5900	0.0674	0.8250
19	0.5800	0.0539	0.5642	0.5800	0.0682	0.7848
20	0.6000	0.0544	0.5776	0.6000	0.0648	0.7976
21	0.5933	0.0552	0.5745	0.5933	0.0681	0.8148
22	0.5467	0.0433	0.5291	0.5467	0.0570	0.7763
23	0.5667	0.0492	0.5498	0.5667	0.0630	0.7821
24	0.5833	0.0536	0.5637	0.5833	0.0661	0.7901
25	0.5600	0.0449	0.5379	0.5600	0.0541	0.6747
26	0.5500	0.0393	0.5259	0.5500	0.0504	0.8077
27	0.5433	0.0417	0.5243	0.5367	0.0541	0.6740
28	0.5533	0.0457	0.5357	0.5533	0.0579	0.7089
29	0.5833	0.0539	0.5623	0.5833	0.0649	0.7108
30	0.5667	0.0470	0.5462	0.5667	0.0580	0.7407

B: Calculated Parameters for Samples from Niger State

S/N	AMG	GMD	SMD	EQD	SC	AR
1	0.5567	0.0397	0.5321	0.5567	0.0544	0.9726
2	0.4967	0.0340	0.4830	0.4967	0.0493	0.7391
3	0.4767	0.0307	0.4633	0.4767	0.0444	0.6232
4	0.5700	0.0415	0.5391	0.5700	0.0472	0.6705
5	0.5500	0.0484	0.5286	0.5500	0.0550	0.8919
6	0.5667	0.0507	0.5528	0.5667	0.0704	0.9167
7	0.5267	0.0406	0.5132	0.5267	0.0580	0.8286
8	0.5100	0.0362	0.4958	0.5100	0.0532	0.8382
9	0.4933	0.0323	0.4780	0.4933	0.0468	0.7536
10	0.5267	0.0398	0.5118	0.5267	0.0561	0.8169
11	0.5300	0.0412	0.5170	0.5300	0.0610	0.8971
12	0.5300	0.0423	0.5174	0.5300	0.0620	0.8824
13	0.5133	0.0392	0.4945	0.5133	0.0576	0.7941
14	0.5233	0.0384	0.5076	0.5233	0.0541	0.8169
15	0.5333	0.0395	0.5158	0.5333	0.0549	0.8472
16	0.5467	0.0457	0.5337	0.5467	0.0682	0.9851
17	0.5467	0.0457	0.5337	0.5467	0.0682	0.9851
18	0.5700	0.0506	0.5550	0.5700	0.0723	1.0000
19	0.5600	0.0447	0.5409	0.5600	0.0630	0.9859
20	0.5667	0.0490	0.5507	0.5667	0.0690	0.9718
21	0.5467	0.0471	0.5344	0.5467	0.0682	0.8986
22	0.5500	0.0375	0.5246	0.5500	0.0513	0.9589
23	0.5000	0.0308	0.4807	0.5000	0.0452	0.8676
24	0.5200	0.0367	0.4984	0.5200	0.0468	0.8472
25	0.5100	0.0305	0.4871	0.5100	0.0441	0.9130
26	0.5533	0.0471	0.5397	0.5533	0.0682	0.9565
27	0.5267	0.0405	0.5344	0.5267	0.0570	0.8028
28	0.5500	0.0422	0.5257	0.5500	0.0648	0.9855
29	0.5500	0.0428	0.5257	0.5433	0.0611	0.9710
30	0.5167	0.0379	0.5025	0.5167	0.0541	0.8000

C: Calculated Parameters for Samples from Oyo State

S/N	AMD	GMD	SMD	EQD	SC	AR
1	0.4773	0.0268	0.4560	0.4733	0.0434	0.9672
2	0.4887	0.0312	0.4731	0.4867	0.0500	0.9355
3	0.5867	0.0417	0.5543	0.5867	0.0496	0.8452
4	0.4700	0.0197	0.4409	0.4700	0.0289	0.8553
5	0.5700	0.0544	0.5596	0.5700	0.0755	0.8750
6	0.4900	0.0360	0.4833	0.4900	0.0571	0.7770
7	0.5100	0.0320	0.4887	0.5100	0.0444	0.8056
8	0.5467	0.0454	0.5276	0.5467	0.0631	0.4305
9	0.5500	0.0454	0.5349	0.5500	0.0631	0.8750
10	0.5030	0.0372	0.4939	0.5030	0.0609	0.9672
11	0.5033	0.0366	0.4938	0.5033	0.0590	0.9355
12	0.5033	0.0359	0.4915	0.5033	0.0561	0.9063
13	0.5000	0.0339	0.4933	0.5000	0.0522	0.8923
14	0.5100	0.0349	0.4942	0.5100	0.0529	0.9242
15	0.5400	0.0426	0.5247	0.5400	0.0599	0.8732
16	0.5833	0.0525	0.5658	0.5833	0.0710	0.9855
17	0.5833	0.0536	0.5671	0.5833	0.0744	1.0000
18	0.5833	0.0513	0.5639	0.5833	0.0658	0.8718
19	0.5467	0.0422	0.5289	0.5467	0.0612	0.9855
20	0.5067	0.0372	0.4959	0.5067	0.0590	0.9365
21	0.4933	0.0279	0.4711	0.4933	0.0399	0.8143
22	0.4900	0.0324	0.4774	0.4900	0.0522	0.9355
23	0.5600	0.0437	0.5395	0.5600	0.0615	1.0000
24	0.5367	0.0429	0.5212	0.5333	0.0630	0.8971
25	0.5267	0.0409	0.5395	0.5267	0.0620	0.9393
26	0.5533	0.0333	0.4904	0.5067	0.0475	0.8143
27	0.5600	0.0447	0.5408	0.5600	0.0621	0.9583
28	0.5733	0.0492	0.5555	0.5730	0.0686	0.9861
29	0.5367	0.0404	0.5198	0.5367	0.0594	0.9706
30	0.5033	0.0366	0.4929	0.5033	0.0590	0.9516

D: Measured Diameters for Samples from Kogi State

S/N	A	B	C
1	0.82	0.71	0.29
2	0.99	0.62	0.26
3	0.78	0.69	0.25
4	0.75	0.63	0.32
5	0.89	0.67	0.22
6	0.83	0.62	0.31
7	0.84	0.63	0.29
8	0.83	0.70	0.32
9	0.81	0.68	0.24
10	0.80	0.66	0.30
11	0.78	0.71	0.31
12	0.92	0.75	0.24
13	0.88	0.72	0.27
14	0.84	0.73	0.23
15	0.86	0.70	0.32
16	0.83	0.69	0.25
17	0.81	0.68	0.29
18	0.80	0.66	0.31
19	0.79	0.62	0.33
20	0.84	0.67	0.29
21	0.81	0.66	0.31
22	0.76	0.59	0.29
23	0.78	0.61	0.31
24	0.81	0.64	0.30
25	0.83	0.56	0.29
26	0.78	0.63	0.24
27	0.77	0.58	0.28
28	0.79	0.56	0.31
29	0.83	0.59	0.33
30	0.81	0.60	0.29

E: Measured Diameters for samples from Niger State

S/N	A	B	C
1	0.73	0.71	0.23
2	0.69	0.51	0.29
3	0.69	0.43	0.31
4	0.88	0.59	0.24
5	0.74	0.66	0.32
6	0.72	0.66	0.32
7	0.70	0.58	0.30
8	0.68	0.57	0.28
9	0.69	0.52	0.27
10	0.71	0.58	0.29
11	0.68	0.61	0.30
12	0.68	0.60	0.31
13	0.68	0.54	0.32
14	0.71	0.58	0.28
15	0.72	0.61	0.27
16	0.67	0.66	0.31
17	0.67	0.66	0.31
18	0.70	0.70	0.31
19	0.71	0.70	0.27
20	0.71	0.69	0.30
21	0.69	0.62	0.30
22	0.73	0.70	0.22
23	0.68	0.59	0.23
24	0.72	0.61	0.23
25	0.69	0.63	0.21
26	0.69	0.66	0.31
27	0.71	0.57	0.30
28	0.69	0.67	0.29
29	0.70	0.68	0.27
30	0.70	0.56	0.29

F: Measured Diameters for samples from Oyo State

S/N	D1	D2	D3
1	0.61	0.59	0.22
2	0.62	0.58	0.26
3	0.84	0.71	0.21
4	0.68	0.58	0.15
5	0.72	0.63	0.36
6	0.63	0.49	0.35
7	0.72	0.58	0.23
8	0.72	0.61	0.31
9	0.72	0.63	0.30
10	0.61	0.59	0.31
11	0.62	0.58	0.31
12	0.64	0.58	0.29
13	0.65	0.58	0.27
14	0.66	0.61	0.26
15	0.71	0.62	0.29
16	0.74	0.71	0.30
17	0.72	0.72	0.31
18	0.71	0.68	0.29
19	0.69	0.68	0.27
20	0.63	0.57	0.21
21	0.70	0.57	0.21
22	0.62	0.58	0.27
23	0.71	0.58	0.26
24	0.68	0.61	0.31
25	0.66	0.62	0.30
26	0.70	0.57	0.25
27	0.72	0.69	0.27
28	0.72	0.71	0.29
29	0.68	0.66	0.27
30	0.62	0.59	0.30

G: Angle of Repose for Samples from Kogi State

	A	B	C
Weight	4.7cm	4.8cm	4.4cm
Base	27cm	26cm	25cm
Angle of repose	19.20°	20.27°	19.39°

H: Angle of Repose for Samples from Niger State

	A	B	C
Weight	5.2cm	4.7cm	4.4cm
Base	26.8cm	25.1cm	25.1cm
Angle of repose	21.21°	20.53°	19.32°

I: Angle of Repose for Samples from Oyo State

	A	B	C
Weight	4.9cm	4.8cm	4.8cm
Base	25.4cm	24.5cm	24.5cm
Angle of repose	21.10°	21.16°	21.39°

J: 1000 Seed Weight

Sample	A	B	C
Kogi	216.2	216.5	220.5
Niger	210.7	211.0	207.9
Oyo	194.5	200.1	197.5

K: Surface Area

Samples	A (g/1000)	B(g/1000)	C(g/1000)
Kogi	3.12	3.16	3.00
Niger	2.68	2.56	2.68
Oyo	2.56	2.40	1.92

L: Bulk Density for the three samples of Parkia biglobosa

Samples	A(g/cm^3)	B(g/cm^3)	C(g/cm^3)
Kogi	0.7798	0.7802	0.7798
Niger	0.8083	0.8086	0.8083
Oyo	0.8574	0.8377	0.8373

M: Particle Density for the three samples of Parkia biglobosa

Samples	A(g/cm^3)	B(g/cm^3)	C(g/cm^3)
Kogi	0.8717	0.8159	0.8181
Niger	0.8253	0.8243	0.8157
Oyo	0.9125	0.9118	0.9132

N: Porosity for the three samples of Parkia biglobosa

Samples	A%	B%	C%
Kogi	10.54	4.38	4.68
Niger	0.90	1.97	2.06
Oyo	6.04	8.13	8.31