DETERMINATION OF PHYSICAL AND MECHANICAL PROPERTIES OF GINGER (*Zingiber Officinale Roscoe*)

BY

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DECLARATION

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 Information derived from personal communication, published and unpublished work were duly referenced in the text.

Bello, Wasiu Olalekan

01\03\2012

Date

CERTIFICATION

This project entitled "Determination of Physical and Mechanical properties of Ginger (Zingiber officinale *Roscoe*)" by Bello Wasiu Olalekan, meets the regulations governing the award of the degree of Bachelor of Engineering (B.ENG.) of the Federal University of Technology, Minna, and it is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This Project is dedicated to Almighty Allah who in is infinite mercy guided me through my academic pursuit. And to my irreplaceable sister, Mrs Balqees Kazeem.

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ABSTRACT

This study was carried out to determine some physical and mechanical properties of ginger (*Zingiber Officinale Roscoe)*.The mean value for moisture content of fresh ginger rhizome was 86.56% (wet basis). The physical and mechanical properties of the agricultural products are necessary for the design of equipment to handle, transport process and store the products. The mean values of length, width and thickness were 90.23mm, 41.23mm and 8.82mm respectively. The mean values of arithmetic mean diameter, geometric mean diameter and equivalent mean diameter were 46.66mm, 30.44mm, and 28.08 respectively. The mean values of sphericity, aspectic ratio,weight and volume were 34.43%, 0.45, 0.39N and 230cm^3 respectively. The mean values of bulk density, true density, porosity, and surface area were 469.67kg/m^3, 1091.40kg/m^3, 56.80% and 3182.60mm^2. The mean value of compressive strength were 15.75MPA.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Ginger (*Zingiber officinale Roscoe)* is the oldest rhizome widely domesticated as a spice. In *De Materia Medica, Discoscoriders and Gaius Plinus Secondus* mentioned ginger among the 600 plants in their writings and by 176AD, ginger was included in the list of taxed imports in Alexandria. In the 9th century, ginger was known in Europe and Marco polo was believed to be the first European to have seen the plant. By the 11th Century ginger was recommended for the cure of plague in England while the Spaniards introduced the plant into the West Indies and Mexico. The Portuguese brought ginger into the west Africa by the I6th Century while supplies of split-dried ginger was already traded in Sierraleone in1819. The cultivation of ginger commenced in Nigeria in 1927 and locations include Southern Kaduna, Nassarawa, Benue,Niger, Gombe, Plateau. Today ginger is cultivated nation-wide (Okwuowulu,1987). Other major producers of ginger are Brazil, Jamaica, Nigeria, Thailand, Australia, Fiji, Philippians, Bangladesh and Indonesia (FAO,1999). In 1807, an English botanist, William Roscoe (1753-1831) named the plant *Zingiber officinale* in his publication. This plant is a monocotyledonous perennial plant although it is cultivated as an annual crop and propagated vegetatively by cuttings the fresh rhizomes (Sutherland, 1981). Ginger is propagated by planting rootstalk cuttings and has been under this type of cultivation for so long that it no longer goes to seed.

The leafy stems of ginger grow about a metre high. The leaves are 15 to 30cm long, elongate, alternate in two vertical rows, and arise from sheaths enwrapping the stem. The flowers are in dense, cone-like spikes about 2cm thick and 4 to 6cm long composed of overlapping green bracts, which may be edged with yellow. Each bract encloses a single, small, yellow-green and purple flower. The whole plant is refreshingly aromatic, but it is the underground rhizome, raw or processed, that is valued as spice. Its medical value is increasingly being recognized. The Chinese prescribe ginger tea for delayed menstruation. It is rich in vitamin C, and Chinese mariners ate it fresh to ward off scurvy (Langner *et al.*, 1988). In Nigeria, traditionally ginger has been used to treat a wide range of ailments including gastrointestinal disorder such as stomach aches, abdominal spasm, nausea and vomiting as well as in arthritis and motion sickness (Langner *et al.*, 1998). Ginger is a good source of potassium, magnesium, copper, manganese and vitamin B6 (NRCRI, 1987).

In the handling, storage and design of processing machineries for agricultural materials knowledge of basic properties of these materials are required. The physical and mechanical properties among others are important in the design of machines and equipment for various agricultural operations. For example, shapes and weight are important design parameters in pneumatic conveying of agricultural products, knowledge of moisture content, volume and density play an important role in numerous technological processes and in evaluation of product quality during drying and storage of agricultural materials and also in the design of silo and other storage structures (Olaniyan and Oje, 2003)

1.2 Statement of the Problem

The shortage of processing machines and equipments for ginger are insufficient and not available in some cases. Also, most agricultural products are visco-elastic, therefore, determining the engineering properties are difficult and complicated, since they are apparently affected by temperature, moisture content and the rate of loading (Zoerb and Hall, 1993).

1.3 Objectives of the Study

The objectives of this work include

i. Determination of physical properties of ginger rhizome

ii. Determination of mechanical properties of ginger rhizome.

iii.

1.4 Justification of the Problem

There is little or no research on ginger handling and processing hence no known research information on ginger production and processing for the Nigerian Farmers. Farmers are therefore handling and processing their ginger using primitive practices inherited from ancient traditions resulting in poorly and unhygienically processed ginger (Maigida and Kudi, 2000). There is need to determine the physical and mechanical properties of ginger rhizome as it plays an important role in the design of equipment for handling, transporting, processing, storing and assessing the product quality.

1.5 Scope of the Study

This study is limited to the determination of some selected engineering properties of ginger rhizome so as to establish convenient reference data for their mechanization and processing. Such properties include; size, shape, colour, weight, volume, true density, bulk density, porosity, surface area, , sphericity, and compressive strength

CHAPTER TWO

2.0 LITERATURE REVIEW

The spice ginger is the underground rhizome of the ginger plant, known botanically as *Zingiber officinale*. This plant originates from Indian, China and Java; however, it is widely grown in African countries including Nigeria. Ginger is a perennial herb and grows to about 3-4 feet high with a thick spreading tuberous rhizome (Menta, 1987).

Ginger produces clusters of white and pink flower buds that bloom into yellows. Every year it shoots up a stalk with narrow spread shaped leaves as well as white or yellow flowers growing directly from the root. It is a spice vegetable substance because it has a distinctive flavour and aroma, thus, it is used to season food. Other examples are dove, cinnamon, nutmeg, pepper, garlic, onion and curry (Guralink, 1984). The characteristic odour and flavour of ginger is caused by a mixture of zingerone, shogaols and gingerols. The dried rhizome contains volatile oils and its extractives are the essentials oils and oleoresins, these extractives are reformulated to produce secondary products such as essence, emulsion and fat based spices (Health and Reinccius, 1986).

In Nigeria, Ginger is used as spices and sometimes, they can be stewed in boiling water to make ginger tea and the oil from it is used for medical purposes (Bode, 2003). The pungent taste of ginger is due to non-volatile phenyl propernoid derived compounds, particularly gingers and shogoals which form gingerols when ginger is dried or cooked. Zingerone is also produced from gingerols during this process, this compound is less pungent and has a spicy sweet aroma (Govindarajan, 1982). Photochemical studies showed that ginger plants are rich in large number of substances including zingiberene, and bisabolene, (Jolad *et al.*, 2005). These compounds have been reported to display diverse biological activities such as antioxidants (Jolad *et al.*, 2005). Traditionally, ginger has been used to treat a wide range of ailments including gastrointestinal disorders such as stomach aches, abdominal spasms, nausea and vomiting as well as arthritis and motion sickness (White, 2007).

2.1 Description of Ginger

Ginger (*Zingiber officinàle*) is a commodity that is highly valued in international markets for its aroma, pungency oil and aleo resin content. It is a tropical monocotyledons herbaceous perennial plant (NRCRI, 1987) with leafy shoots and grows to a height of 30-100m, depending on cultivars and growing environment. Nigeria is the third largest exporter of ginger in the world after china and India. Most of the dried ginger that are available for international trade are simply sun dried over a few days, but artificial drying is also used in areas lacking a defined dry season to coincide with the harvest. The rhizome is dried to between 10-12% moisture content. Dried ginger is usually presented in a split or sliced form. Splitting is said to be preferred to slicing, as slicing loses more flavour, but sliced are easier to grind and this is the predominant form of ginger currently in the market. Fumen *et al.*, (2003) also reported that farmers continue to process their ginger into split-dried form because that is the form demanded by the local ginger market. Other reasons for the wider acceptability of the split-dried ginger over the peeled-dried form may also be attributed to the fact that the flavour components of ginger are concentrated just below the peel, hence great losses are encountered in the peeling process (Ashurst *et al.,* 1973).

While splitting process has been found to conserve about 15-20% ginger material, which is lost during peeling process it also facilitates fast and thorough drying of ginger (Meadows, 1988; Akomas and Oti, 1988). Ginger splitting also minimizes loss of volatile oil components; hence split-dried ginger is most suitable for industrial distillation and extraction of volatile oil and oleoresin (Ebewele and Jimoh, 1981).

The two popular varieties produced in the country are the yellowish variety with plump rhizomes and black or dark variety with small compact rhizomes (Erinle, 1988). The yellow variety is richer in flavour, of better colour and appearance and also better and more suitable for ginger powder production. Nigerian ginger is highly valued in international market for its aroma, pungency, high oil and oleoresin content (Njoku, *et al.,* 1995).

2.2 Geographical Distribution

Ginger has been grown in tropical Asia since ancient times. Wild forms of ginger have not been found and its origin is uncertain, although it is thought to come from India. It was brought to Europe and East Africa by Arab traders from India. Together with pepper, ginger was one of the most commonly traded spices during the 13th-14th Centuries. From East Africa, the Portuguese brought ginger to West Africa and other regions of the tropics during the 16th Century. At about the same period the Spanish introduced ginger into Jamaica, which still produces high quality ginger. According to (NRCRI, 1987) ginger is unknown in a wild state and has been cultivated in tropical Asia since ancient times At present, ginger is cultivated throughout the humid tropics. In Nigeria, ginger is produced in the following states of the federation namely, Kaduna, Nasarawa, Benue, Niger and Gombe with Kaduna as the major producer. Nigeria's production in 2005 was estimated at 110,000metric tonnes (FAO, 2009). Out of this 10% is locally consumed as fresh ginger while 90% is dried primarily for the export market.

2.3 Propagation

Ginger is propagated by pieces of rhizome called seed pieces or sets (vegetative). They are normally produced by cutting rhizomes into 3-6cm long pieces of 30-60g, with at least one growing point or bud. Medium to large-sized seed pieces produce more vigorous plantlets and higher yields than small ones. To prevent diseases, seed pieces may be dipped in a fungicide solution and air-dried prior to planting. Seed pieces can be pre-germinated to obtain uniform plants, reduce the number of missing hills in the field and allow for once-over harvesting. Pre-germination may be promoted by placing the sets 2.5cm apart on raised beds, covered with compost, sawdust or manure or both and kept moist. The sets are ready for transplanting after 3-5 weeks or when the sprouts are 1-2cm long (NRCRI, 2004).

2.4 Planting

The best time for planting ginger is winter and early spring. For the plantation of ginger roots, the soil should be well prepared the soil after heavy frost is over. You can add farmyard compost with the garden soil in 1:1 proportion. In case of wet garden soil and heavy type, it is require to raising beds in order to minimize excessive water accumulation. Doing so ensures proper drainage of water and prevents water logging. Ginger plants can be grown either in the garden or in the pots and containers. The basic requirements of ginger plants for a good harvest are fertile soil, proper drainage, filtered sunlight, high humidity and warm climatic conditions. A few things to avoid while planting ginger are waterlogged soil, full sunlight, very strong winds, cold temperature conditions and heavy frost. Before planting ginger, the field should be thoroughly prepared to a fine tilth, free of weeds, roots and residues of previous crops. Normally, ginger is planted in rows, with 25-30cm between rows and 15-35cm within the row. In the Philippines, the recommended planting distance is 50-70cm between rows and 30cm within the row. The normal planting depth is 5-12cm (NRCRI, 1987). Plates 2.1 and 2.2 below shows the ginger plant and ginger rhizomes

Plate 1: Ginger Plant

Plate 2: Ginger Rhizomes

At planting time, the soil must be moist and not dry out once the sets are planted. The preferred soil temperature at planting is 25°C and should not exceed 30°C. The time to sow ginger in different location of the world is selected to coincide with a period when rainfall have become regular, mid-April in Southern Agricultural zones of Nigeria (Okwor, 1983). It is recommended to practice rotation and to grow ginger only once in 3-4 years, to reduce the incidence of pests and soil borne diseases. Ginger is often found in intercropping systems. It is often the first crop on land taken into cultivation (Okwor,1983).

2.5 Harvesting

Timing of harvesting of ginger rhizomes depends on their intended use, as the relative content (on a dry weight basis) of essential oil, pungent constituents and fibre increases with age of the crop. The best time to harvest ginger is any time after the leaves have died down. Usually it takes eight to ten months to get to that point. Alternatively ginger can be grown in tubs so as to make the harvest easy. In this case there is no need to dig but to just tip out the whole thing. Break up the rhizome, select a few nice ones with good growing buds for replanting. In Nigeria harvesting of ginger starts from October and normally continues until April or May. This largely depends on the market situation as ginger can be left on the ground (not harvested) for two years. The content of essential oil and the pungent principles of the rhizomes reach a maximum about 9 months after planting, decreasing later on, whereas the fibre content continues to increase. When intended for consumption as a fresh vegetable (green ginger), rhizomes may be harvested about 5 months after planting. For the production of preserved ginger, they are usually harvested 5-7 months after planting, before they are fully mature and while still tender, succulent and mild in pungency, and with low fibre content (Akomas and Oti, 1988).

For dried ginger, mature rhizomes that have developed a full aroma, flavour and pungency are used. These are harvested 8-9 months after planting, when leaves begin to yellow and stems start to lodge. Harvesting is accomplished either by hand with a spade, hoe or digging fork, or by mechanical diggers. Harvesting should be done very carefully, to minimize damage to the rhizomes. Delaying harvesting after maturity is reached will reduce the rhizome quality, decrease the storage life and increase the incidence of sprouting during storage. Figures 2.1 and Fig 2.2 show the flow chart for dried, preserved and essential ginger.

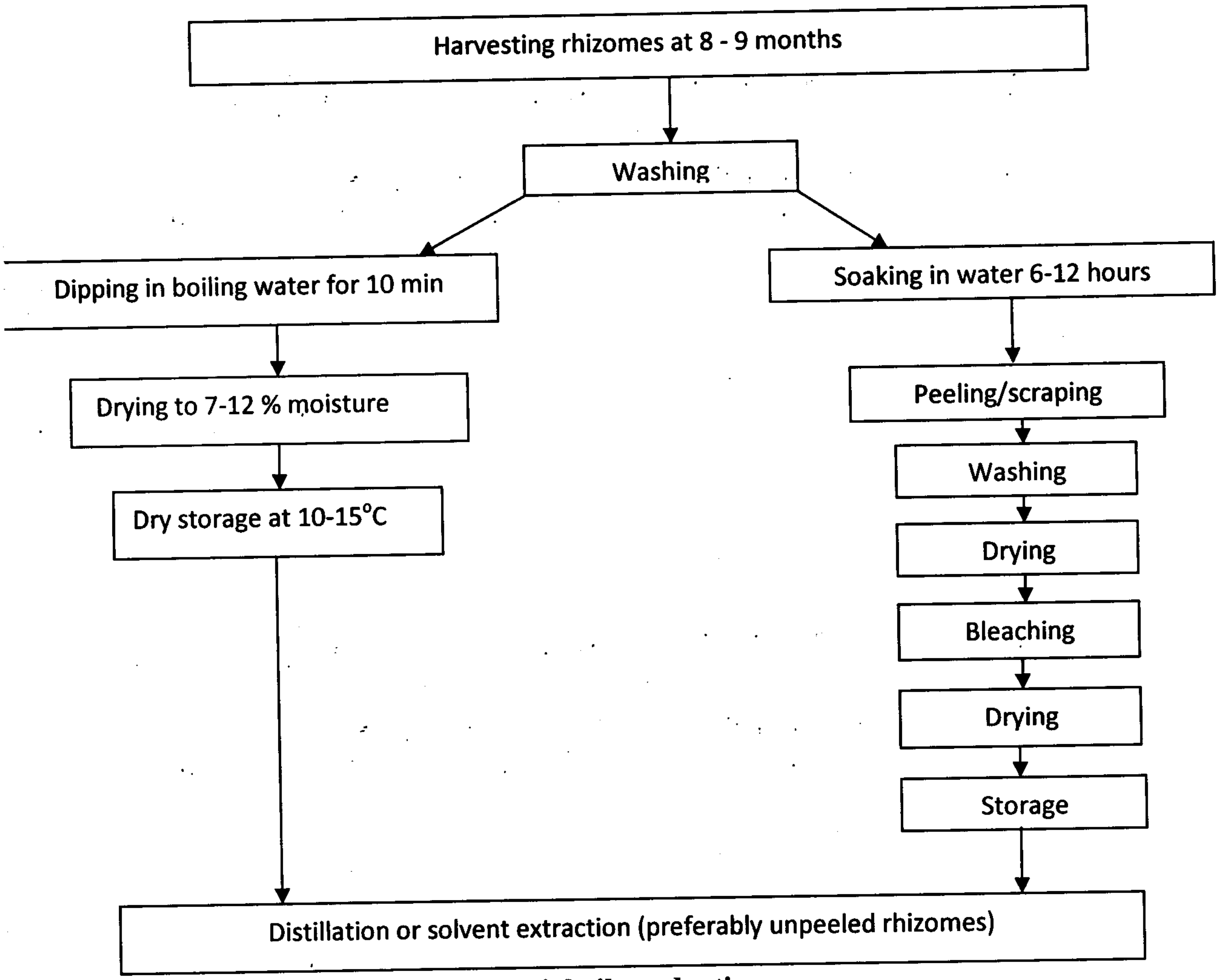

FIG 2.1: Ginger dry spices for essential oil production

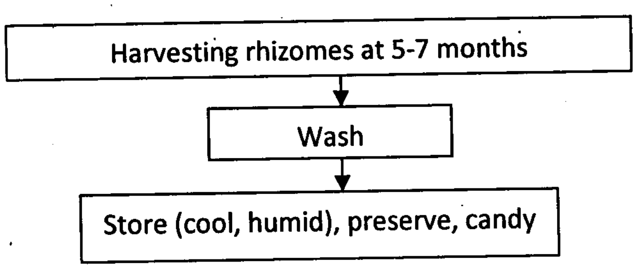

FIG 2.2: Fresh or preserved ginger

2.6 Production and International trade

The bulk of the production of ginger is consumed locally in the producing countries, mainly as fresh ginger. In the 1980s, world production was estimated at about 100,000 tonnes per year, of which about 25,000 tonnes were exported mainly by India. Other sources estimated annual world production of ginger in the early 1980s at 300,000 tonnes, growing steadily to 500,000 tonnes in 1990 and 600,000 tonnes in 1998, with India, China, Indonesia and Nigeria being the main producers (FAO, 1999). In South-East Asia, large amounts are also produced in Philippines and Thailand. Tables 2.1 shows the world's producer of ginger. World production of ginger oil in the 1980s was estimated at 30 tonnes annually, of which 20 tonnes were exported mainly by India and China, the main markets being the USA, the European Union and Japan. The world production of ginger oleoresin was in the 1980s at about 150 tonnes annually, with the major producers being the USA, India and Singapore. Ginger production in Nigeria dates back to 1927 (Arene *et al.*, 1987) with production initially concentrated around the southern area of Kaduna State (Onwueme, 1988). Exportation of the crop started just before the Second World War (NRCRI, 2004). Between 1960 and 1986, Nigeria exported a total of 56,224,519 tonnes of ginger valued at 618,812 dollars to European and Northern America countries (FAO, 1999). In Nigeria, the major export market for ginger include United kingdom, Germany, Spain, Netherlands, France, United States of America, Russia, Saudi Arabia among others and the export foreign board price varies from USD 2500-3500/ MT depending on the type and form in which the ginger is packaged and also the negotiation made with the buyers.

COUNTRY	AREA (000' ha)	PRODUCTION (000'tons)	PRODUCTIVITY (tons/ha)
India	105.50	517.8	4.9
China	24.50	279.0	11.3
Indonesia	18.20	159.0	8.7
Nepal	12.90	154.1	12.0
Nigeria	191.00	134.0	0.7
Bangladesh	7.70	49.4	6.4
Thailand	14.00	34.0	2.4
Philippines	3.90	27.2	6.9
Cameroon	1.30	7.5	5.7
USA	0.04	1.9	47.5
Rest of world	8.20	71.5	8.7
World	**387.30**	**1,476.9**	**3.8**

Source: http://faostat.fao.org (2006).

2.7 Uses of ginger

The list of ginger uses is almost endless, being a pungent spicy herb and one of the popular food spices. They range from baked production like ginger bread, ginger biscuits, ginger cookies to drinks like ginger tea, ginger beer and so forth. Ginger contain about 1-2% oil. The oil is extracted and distilled from rhizome for various uses in confectionary, perfumery, beverages and pharmaceuticals and soft drink concentration (Asummugha, 2003). It can also serve as additives in the preparation of roasted meat (*Suya*) as well as some local drinks like '*Kunu*" (Chukwu, 2003). Dried ginger is used predominantly for flavouring coffee especially in the Middle East. It contains medicinal qualities and it is also used to aid digestion. Traditionally, ginger has been used to treat a wide range of ailments including gastrointestinal disorder such as stomach aches, abdominal spasm, nausea, vomiting, arthritis as well as motion sickness (White, 2000). Ginger is widely used as a spice, with its three main products being fresh ginger, dried whole or powdered ginger, and preserved ginger. Fresh ginger is prepared from immature or mature rhizomes, the more pungent and aromatic dried ginger from mature rhizomes, and preserved ginger from immature rhizomes. The dried and preserved products are the major forms of internationally traded ginger, whereas fresh ginger is the major form of ginger consumed in the producing regions.

Ground dried ginger is applied worldwide for domestic and culinary (kitchen) purposes, and also extensively in the flavouring of processed foods, especially in bakery products. Preserved ginger is used for domestic culinary purposes and in the production of processes of foods such as jams, marmalades, cakes and confectioneries. The fresh and dried rhizomes yield an essential oil ('ginger oil') and oleoresin ('ginger extract'). Ginger oil has the aroma and flavour of the spice, but lacks pungency. It is used for flavouring beverages, in confectionery, and in cosmetics, perfumes and pharmaceuticals. Ginger oleoresin has the aroma, flavour and pungency of the spice itself. It is used for flavouring beverages and for similar purposes as the ground spice. It is seldom applied in cosmetics and perfumes because of its poor solubility in alcohol, but is used more often in pharmaceutical. Ginger has been used medicinally in Asia since ancient times, for example, in China and India. It is still widely used in folk medicine, especially as a carminative, stimulant of the gastro-intestinal tract. Rhizome products are applied against a wide range of ailments, including nausea, and diarrhorea. In Malaysia, leaves are eaten against stomach ache and rheumatism, and young shoots may be used for lotions against rheumatism. In the Philippines, ginger tea is traditionally drunk to prevent hoarseness. Ginger is also applied as an antidote against snake poison in Indonesia, and fish and crab poison in China (Lagner *et al.,* 1988)

2.8 Drying and Storage of Ginger

In order to achieve the main objective of drying ginger, the rhizome should be washed as soon as possible after harvesting as soil is more difficult to remove when dry. Each rhizome should be washed in water to give a fresh appearance. Care should be taken to prevent breakage. After washing, dipping in 150ppm GA3, and or 750 ppm benlate followed by storage in moist saw-dust (Okwuowulu and Nnodu, 1988).This will assist in minimizing microbial damage and may improve presentation. After washing and dipping, rapid drying is required in a well ventilated area. Prolonged periods of drying in sunlight is to be avoided as water loss and shriveling will occur. In the case of long term storage, it is recommended to treat with fungicide (Thiabendazole 0.05%) in addition to sodium hypochloride since this will assist in reducing spoilage. The treatment should be given after washing and prior drying. Storage of ginger may be carried out at 12 to 65^{0}C and 75% relative humidity with the rhizomes remaining in a marketable condition for two to three months. Storage at temperature below 10 to 12^{o}C will result in chilling injury characterized by skin decolouration, high levels of water loss and increased incidence of spoilage organism (Pruthi, 1992).

2.9 Pests and Diseases of Ginger

In general, diseases are more damaging in ginger than pests, so disease prevention or control is an essential component of commercial ginger growing. It has been reported that uncontrolled weed growth in ginger plots may reduce rhizome yield by up to 76% (Njoku *et al.,* 1995) The diseases of ginger include leaf spot, fusarium yellow, spiral nematode, and rhizome rot. The most important diseases are rhizome rots, often caused by Pythium spp., Fusarium spp. and Rosellinia spp. The main symptom is degeneration of rhizomes into a black, putrefying mass whereas above ground the leaf tips, sheaths, margins, and gradually whole leaves turn yellow, followed by desiccation and death. Another widespread and serious disease is bacterial wilt, caused by Ralstonia Solana cearum, which occurs, for instance, in Indonesia, Malaysia, the Philippines and Thailand. The symptoms include progressive yellowing and wilting from the lower leaves to the whole plant, with badly affected stems and rhizomes yielding a milky exudate when cut (Jacob, 1980).

2.10 Control of Pests and diseases of Ginger

Chlororal dimethyl at 12kg au/ha are pre-emergent herbicides which may be applied 1-3 days after planting (Aliyu, *et al.*, 1991). Mulching is the method of protecting the surface of the soil from the hazards of excessive intensives sun shine and rainfall. It is very important to note that ginger shows materials such as rice husk, saw dust, leaf species. Good mulching is found to bring about quick and uniform sprouting and minimizes nematode infestation (Hayness *et al,* I973). Application of heavy mulch, about 5 cm thick with materials such as dry grass, dry leaves and rice husk that will not decay within the first three months after planting is recommended. Ginger has a high nutrient demand from the soil; hence the need for fertilizer application. Njoku et al., (1985) confirmed that nitrogen was the major limiting nutrient militating against massive production of ginger. Application of manure at 25 - 30 tonnes/hectare during land preparation and in-organic fertilizer at 30kg/ha applied 6 – 8 weeks after planting is recommended.

2.11 Physical properties of Ginger

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 ginger to be considered include:

2.11.1 Shape

This is defined as the form 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 equipment. 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 2.2 shows some standard shapes and their description.

Table 2.2: Criteria for Describing Shape and Size

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
Truncated	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 circle

Source: Mohsenin, (1970)

2.11.2 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.

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
4. $AMD = A = \frac{1}{3}[D_1 + D_2 + D_3]$ .... (2.1)
5. $GMD = B = [D_1 \times D_2 \times D_3]^{1/3}$ .... (2.2)
6. $EQD = \frac{A + B + C}{3}$ .... (2.3)
7. $= \frac{GMD}{D_1} \times 100$ .... (2.4)

8. $AR = \frac{D_2}{D_1}$ .... (2.5)

2.11.3 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:

$W=mg$ .... (2.6)

Where, m= mass in kilogram

g=acceleration due to gravity

2.11.4 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.

2.11.1.5 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 centimetres, or in units of liquid measure, such as gallons and litres. 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 solids can be determined experimentally by liquid, gas, or solid displacement methods.
3. Volume can be measured by the 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. 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 SI system, the unit of density is kg/m^3.

2.11.1.6 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 modelling 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).

$$P_f = \left[1 - \frac{\rho_b}{\rho_p}\right] \times 100 \qquad (2.7)$$

2.11.1.7 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.

2.11.8 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 scientists and agricultural engineers as it helps in determining certain adaptation and resistance to processing stages such as drying, storage, cooking, and even consumption. It can be expressed in dry or wet basis.

$$M_c = \frac{W_i - W_f}{W_i} \times 100 \quad \text{.........} \quad (2.8)$$

Where:

M_c = Moisture content, % wet basis

W_i = Initial weight of sample, kg

W_f = Final weight of sample, kg

2.11.9 Sphericity

This is a measure of how spherical (round) an object is. As such, it is a specific example of a compactness measure of a shape. Shericity of a particle can be defined as the ratio of the surface area of a sphere (with the same volume as the given particle) to the surface area of the particle.

2.12 Mechanical Properties of Ginger

These properties are those that have to do with the behaviour of agricultural products under applied forces. According to Anazodo (1983) 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 postharvest system

2.12.1 Compressive Strength

This is a 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 Materials

3.1.1 Selection of Materials

The yellow variety "*Tafin Giwa*" of ginger rhizomes which was used for the work were obtained from the central market in Minna, Niger state.

3.1.2 Apparatus

The equipments used are listed as follows:

1. Venier callipers(Inox)
2. Oven (Gallenkamp, SG93/11/717
3. Measuring Cylinder(Jaytec, BS604)
4. Electronic Weighing balance
5. Universal Testing Machine(Microvision, 4026538MV)
6. Bourn vita Tin

3.2 Methods

The various method used in the determination of physical and mechanical properties of ginger rhizome include:

3.2.1 Preparation of Materials

The samples were cleaned to remove soils that were attachéd to it during harvesting, because these will have effect on the measurements like weight.

3.2.2 Moisture Content Determination

Moisture content of the samples was determined by the method described by (ASAE, 2000). The weight loss of the samples was recorded and the moisture content determined in percentage from equation below:

$$M.C_{wb} = \frac{W_i - W_f}{W_i} \times 100 \quad (3.1)$$

Where $M.C_{wb}$= Moisture content, % wet basis

W_i=Initial weight of sample,kg

W_f=final weight of sample, kg

3.3 Selected Physical Properties of Ginger

3.3.1 Shape determination

To determine the shape of the ginger, tracing of the longitudinal and lateral crosssection of the material was done. This was compared with the shapes listed on a charted standard (Mohsenin *et al*, 1970). Using the standard charts, descriptive terms was used to define the shape of the samples.

3.3.2 Size determination

Ten (10) rhizomes of fresh ginger were selected randomly and numbered 1 to 10. Axial dimensions in terms of major diameter (D1), intermediate diameter (D2), and minor diameter (D3) were measured using a venier caliper reading to 0.01mm precision. While D1, D2, D3 was used to evaluate arithmetic mean diameter (AMD), the geometric mean diameter (GMD), square mean diameter (SMD), the sphericity of the materials under the investigation with the equation below respectively.

$$AMD = A = \frac{1}{3}\,[D_1 + D_2 + D_3] \quad \text{(3.2)}$$

$$GMD = B = [D_1 \times D_2 \times D_3]^{1/3} \quad \text{(3.3)}$$

$$SMD = C = \sqrt{\frac{D_1 D_2 + D_2 D_3 + D_3 D_1}{3}} \quad \text{(3.4)}$$

$$ED = \frac{A+B+C}{3} \quad \text{(3.5)}$$

$$SC = \frac{A+B+C}{3} \quad \text{(3.5)}$$

$$AR = \frac{D_2}{D_1} \quad \text{(3.6)}$$

3.3.3 Weight Determination

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 obtained by the product of the mass measured by the electronics weighing balance and acceleration due to gravity. It's SI unit is Newton (N).

3.3.4 Determination of Sphericity

This is a measure of spheres of some volume as the object. The sphericity of ginger was determined by obtaining the values of major, minor and intermediate diameter of the material. The sphericity was then be calculated using the formula below;

$$Sphericity\ (S) = \frac{\sqrt[3]{abc}}{a} = \frac{Dg}{a} \times 100 \quad \text{......................................} (3.7)$$

Where, a= Major diameter

b=Intermediate diameter

c=Minor diameter

3.3.5 Volume and Density Determination

Water displacement method was used to determine the volume of the product due to its irregular shape (Mohsenin; 1986). The ginger was first weighed on an electronic weighing balance after which water was poured into a cylinder 500cm^3, noting the final level to which the water will rise. The second reading was then obtained when the fresh ginger was immersed in the cylinder. The difference between the final and initial water levels gives the volume of the ginger. The volume and density were then determined using the following expressions:

$$Volume\ V = \frac{Weight\ of\ displaced\ water\ (kg)}{Weight\ density\ of\ water\ (\frac{kg}{m3})} \quad \text{..........................} (3.8)$$

Knowing the weight in air and volume, weight density of the product was determined by the ratio of weight of volume (Mohsenin 1970).

$$Density = \frac{Weight\ of\ the\ product\ in\ air\ (kg)}{Volume\ of\ the\ product\ (m3)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.9)$$

3.3.6 Surface Area

Surface area were estimated by the relationship given by Mohsenin, (1970) which was given as:

$$S = \pi D_g^2 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (3.10)$$

3.3.7 Colour Determination

This is part of light that is reflected when light falls on them. The colours of the samples of ginger were viewed in a visible environment.

3.3.8 Determination of True density

The ratio of weight of ginger to the volume of displaced water was determined as the true density. The particle densities of the samples were determined by dividing the sample mass measure by the electronic weighing balance with the volume determined by the water displacement method.

3.3.9 Determination of Bulk Density

This was be determined by filling a bournvita tin with ginger and weighed. The volume of the cylinder was estimated by knowing the height and radius of the container. The bulk density of samples were then calculated as the ratio of the bulk weight and the volume of the container.

3.3.10 Determination of Porosity

This was computed from the values of the true density and bulk density of the ginger using the expression below for all the samples. A value for porosity can alternatively be calculated from the bulk density and particle density as described by Mohsenin, (1970).

$$P_f = \left[1 - \frac{\rho_b}{\rho_p}\right] \times 100 \quad \text{.......} \quad (3.12)$$

3.4 Mechanical Properties of Ginger

3.4.1 Compressive strength

The machine used was the universal testing machine manufactured by the Micro vision industries. This machine is software driven; manual operations are involved only when loading and unloading a product. The plates for compression testing were fixed in position. The stationary plate at the bottom, the movable plate were attached to the arm that applied the pressure. Pressure is applied by the upper arm pressing down on the product which is placed centrally on the bottom plate, which remained stationary. Sensors attached to the load cells of the machine measured the variations in pressure applied on the product and the dimensions of the product till it failed. All details were saved in the computer system that had been interfaced with the machine.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

The determined Physical and Mechanical properties of ginger rhizomes are presented in Table 4.1 below with their mean, standard deviation and coefficient of variation .

Table 4.1: Results of the determined Physical and Mechanical properties of ginger rhizome

Properties	No of Samples	Maximum	Minimum	Mean	S.D	C.V
Shape	Irregular					
Colour	Yellow					
Moisture content	4	89.05	84.27	86.56	2.03	2.35
Length mm	20	119.00	66.00	90.23	13.01	14.42
Thickness mm	20	17.50	1.00	8.82	5.15	58.39
Arithmetic Mean dia mm	20	65.00	38.67	46.66	7.37	15.28
Geometric Mean dia mm	20	47.17	16.60	30.44	9.28	30.49
Equivalent Mean dia mm	20	56.79	28.08	38.91	7.87	20.23
Weight N	20	0.54	0.22	0.39	0.08	20.51
Volume cm^3	5	235	226	230	3.16	1.37
Sphericity %	20	57.10	14.92	34.43	11.06	32.12
Aspectic Ratio	20	0.84	0.23	0.45	0.16	35.55
Bulk Density Kg/cm^3	5	490.13	460.95	469.67	10.45	2.22
True Density Kg/cm^3	5	1098.00	1009.00	1091.40	66.16	6.06
Surface Area	20	6990.98	884.69	3182.60	1805.09	56.72
Porosity %	5	61.90	53.65	56.80	2.77	4.88
Compressive Strength MPA	4	25	11.00	15.75	5.54	35.17

4.2 Graphical Representation of Results on Compressive Strength

The graphs below shows the graphical representation of the ginger rhizome with different length, width and thickness.

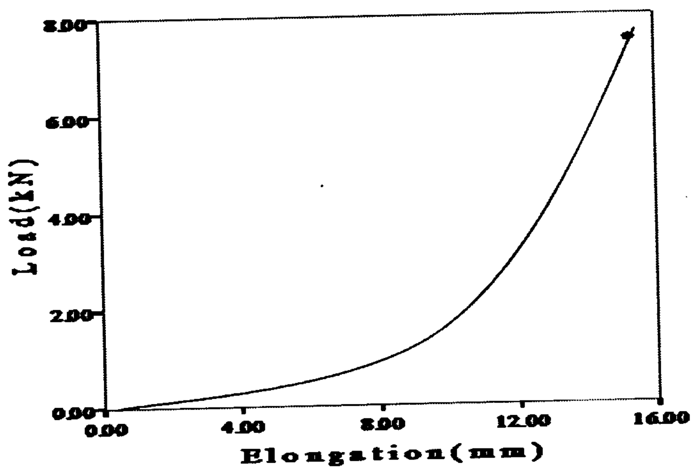

Fig 4.1: Graph of load (KN) against elongation (mm) of Ginger rhizome 1 with length96mm, width 35mm and thickness 19mm.

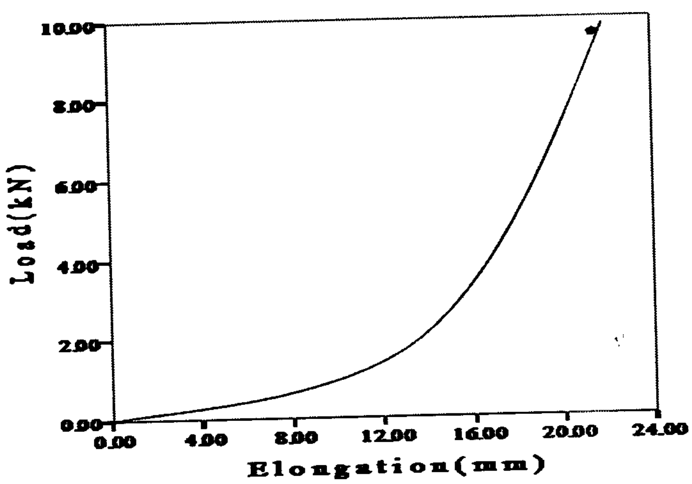

Fig. 4.2: Graph of load (KN) against elongation (mm) of Ginger rhizome with length 72mm, width 45mm and thickness 21mm.

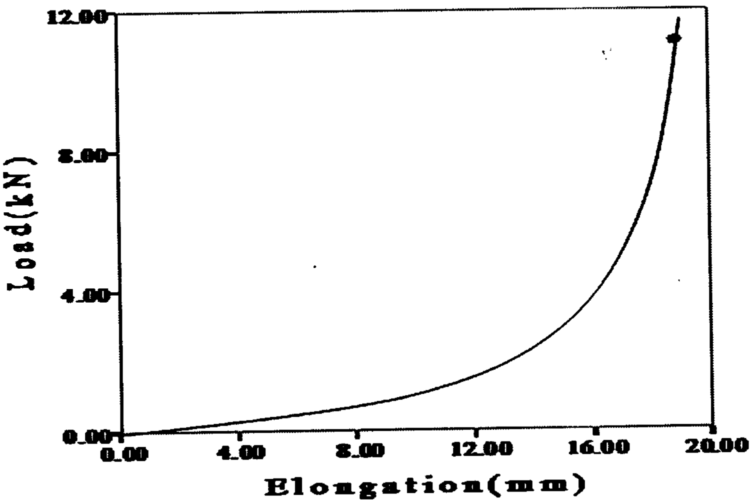

Fig. 4.3: Graph of load (KN) against elongation (mm) of Ginger rhizome 3 with length 71mm, width 47mm and thickness 19mm.

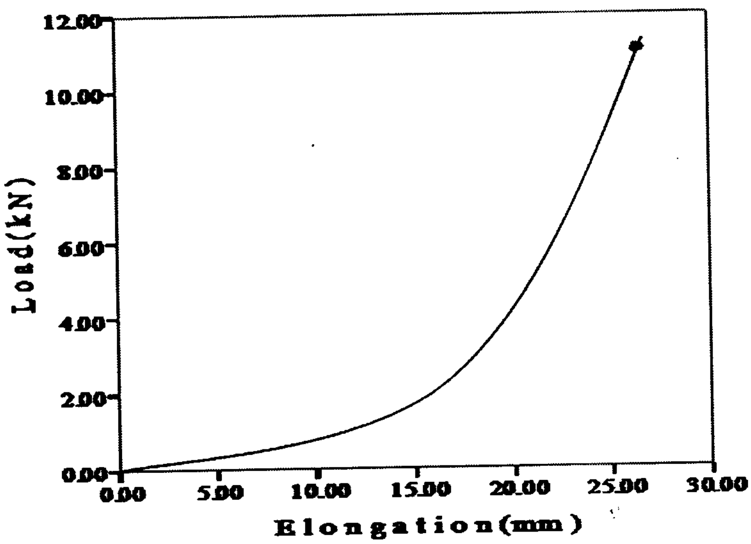

Fig. 4.4: Graph of load (KN) against elongation (mm) of Ginger rhizome 4 with length 71mm, width 35mm and thickness 15mm.

4.3 DISCUSSION OF RESULTS

A summary of the results of the determined physical and mechanical properties of ginger rhizomes were presented in Table 4.1. The mean values of moisture content of ginger rhizomes were found to be 86.56%. Moisture content of the produce determines the shelf life and keeping quality of ginger. *Sreekumar et al.*, (2002) suggested drying of fresh ginger from about 85% moisture to a residual moisture content of about 10% for safe storage and further processing. The mean values of length, width and thickness were found to be 90.23mm, 41.23mm, and 8.82mm while their standard and coefficient of variation were 13.01, 13.86, 5.15 and 14.42% 33.62%, 58.39% respectively as against the value obtained for the length, width and thickness at the India institute of spices research by *Jayashree* and *Visvanathan* (2011) which were 149.9mm, 81.7mm and 44.9mm.

The size and other axial dimensions helps in determining the aperture size of machines, particularly in separation of materials. These dimensions are useful in estimating the size of machine components (Owolarafe and Shontode, 2004). For example, it is useful in estimating the number of ginger pieces that is to be engaged at a time in case of ginger washer, the spacing of slicing discs and number of slices expected from an average piece in case of ginger slicer. The major axis has been found to be useful by indicating the natural rest position of the material and hence in the application of compressive strength to induce mechanical rupture.

The mean values of arithmetic mean diameter and geometric mean diameter were 46.66mm and 30.44mm respectively while their corresponding values of standard deviation and coefficient of variation were 7.37, 9.28 and 15.28%, 30.49% respectively. The geometric mean diameter of the axial dimension is useful in the estimate of the projected area of a particle moving in turbulent or near turbulent region of an air steam. This projected area of the particle is generally indicative of its pattern of behaviours in a flowing fluid such as air, as well as ease of separating extraneous materials from the particle during cleaning by pneumatic means. The mean values of equivalent diameter were 38.91mm while the corresponding values of standard deviation and coefficient of variation were 7.87 and 20.23% respectively.

The mean values of weight, volume and surface area were 0.54N, 110.7cm^3, and 3182.60mm^2 respectively while their corresponding values of standard deviation and coefficient of variation were 0.08, 9.86, 1805.60 and 20.51%, 9.44%, 56.72% compare to the values gotten by *Jayashree* and *Visvanathan (*2011) which was 1.01N, 85.00cm^3 and 194.52cm^2 for the weight, volume and surface area respectively. The mean value of bulk density, true density and porosity were 469.67kg/m^3 , 1091.40kg/m^3 and 56.80% while the corresponding values for standard deviation and coefficient of variation were 10.45,66.16, 2.77 and 2.22 6.06, 4.88 respectively. The mean values obtained by Jayashree and Visvanathan (2001) for bulk density, true density and porosity were 471.49kg/m^3, 1107.01kg/m^3 and 66.80%. These properties are useful in determining the load and space occupied by ginger during transportation (Owolarafe and Shotonde, 2004). The mean values of compressive strength are 15.75 while the corresponding values for standard deviation and coefficient of variation were 5.54 and 0.30 respectively.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The following conclusions were drawn from the determined physical and mechanical properties of ginger (*Zingiber Officinale Roscoe*). The engineering properties determined include shape, size, weight, arithmetic mean diameter, geometric mean diameter, equivalent mean diameter, sphericity, aspectic ratio, colour, volume, particle density, bulk density, porosity, surface area and compressive strength. These were determined at the mean moisture content of 86.56% (wet basis). The length, width and thickness are very low compared to the value obtained by Jayashree and Visvanathan (2011). The mean values of compressive strength were 15.75MPA, thus ginger rhizome requires a lower force during handling and processing operations involving compression. The data obtained from this work would therefore be very useful in the design of post harvest handling and processing operations.

5.2 Recommendations

The following are recommended for further research;

- Other engineering properties of ginger should be worked on to provide fairly comprehensive information in design parameters.
- Standard apparatus or machines should be made available in order to get more accurate results and also to be able to determine other properties of biomaterials
- Determination of engineering properties of other varieties of ginger is to be encouraged.

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APPENDICES

APPENDIX I

VALUES OF SELECTED PHYSICAL PROPERTIES OF GINGER RHIZOME

S/N	D1 (mm)	D2 (mm)	D3 (mm)	Mass (g)	Weight (N)	A.M.D (mm)	G.M.D (mm)	S.M.D (mm)	E.Q.D (mm)
1	88.00	26.00	2.00	46.68	0.46	38.67	16.60	28.96	28.08
2	94.00	39.50	10.00	45.20	0.44	47.83	33.36	41.02	40.74
3	95.00	22.00	4.00	33.60	0.33	40.33	20.30	29.20	29.94
4	78.00	40.00	3.50	40.40	0.40	40.50	22.19	34.32	32.34
5	66.00	38.00	12.00	32.00	0.31	38.67	31.11	35.38	35.05
6	79.00	26.50	4.00	48.50	0.48	36.50	20.31	28.96	28.59
7	119.00	63.00	14.00	55.50	0.54	65.33	47.17	57.86	56.79
8	83.00	45.00	17:50	42.50	0.42	48.50	40.28	44.63	44.47
9	96.50	26.00	6.00	45.20	0.44	42.83	24.69	32.88	33.47
10	92.00	51.00	10.50	44.54	0.44	51.17	36.66	45.44	44.42
11	112.50	42.00	1.00	42.40	0.42	51.83	16.78	40.33	36.31
12	84.00	35.00	7.00	39.08	0.38	42.00	27.40	35.46	34.95
13	99.50	32.00	8.50	32.59	0.32	46.67	30.02	37.87	38.19
14	86.00	41.00	10.50	40.68	0.40	45.83	33.33	40.25	39.80

15	71.50	56.00	17.00	24.88	0.24	48.17	40.83	45.36	44.79
16	77.50	23.00	3.00	38.62	0.38	41.17	18.88	29.46	29.84
17	73.50	44.00	5.50	46.02	0.45	41.00	26.10	35.96	34.35
18	87.50	48.00	17.00	23.88	0.23	50.83	41.49	46.56	46.29
19	102.00	47.50	15.00	45.60	0.45	54.83	41.73	48.61	48.39
20	94.00	79.00	8.40	22.85	0.22	60.46	39.65	54.40	51.50
Mean	90.23	41.23	8.82	39.51	0.39	46.66	30.44	39.65	38.91
S.D	13.01	13.86	5.15	8.48	0.08	7.37	9.28	8.18	7.87

APPENDIX II

Plate 3: Weighing Balance

Plate 4: Ginger Sample

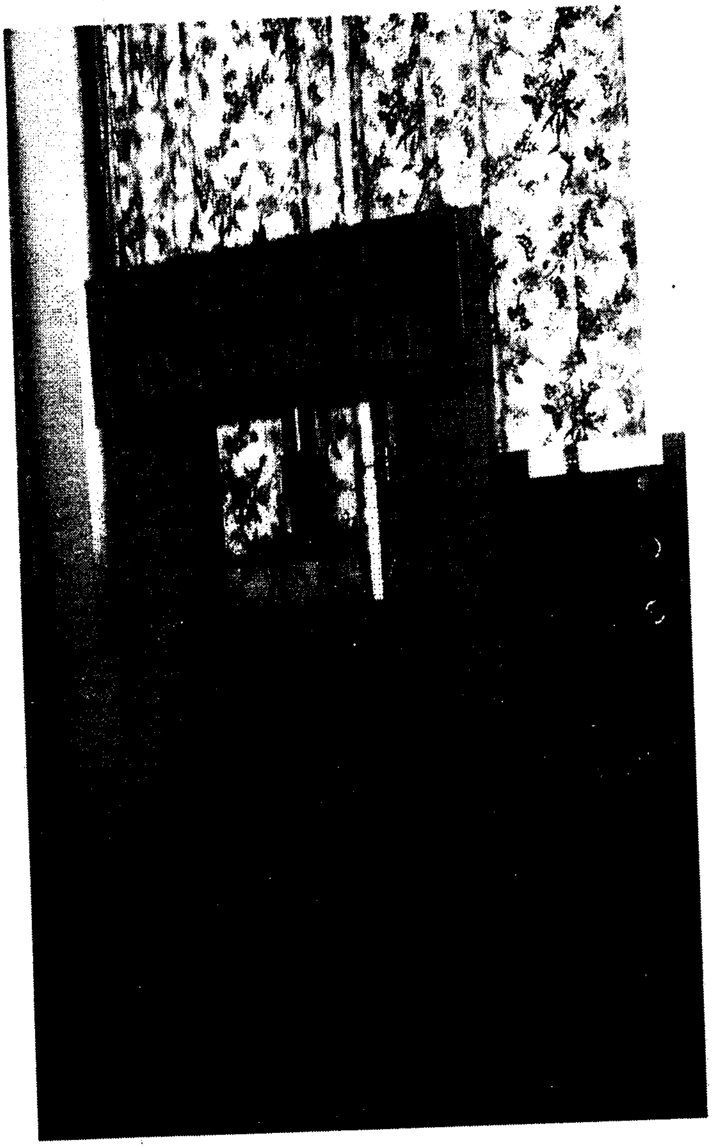

Plate5: Universal Testing Machine