DETERMINATION OF SOME PHYSICAL AND MECHANICAL PROPERTIES OF LOCUST BEAN SEEDS.

BY

UDENZE JOY CHIDIMMA

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NOVEMBER, 2006.

DECLARATION

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 Information derived from personal communications, published and unpublished works of others were duly referenced in the text.

20/11/2006

UDENZE JOY CHIDIMMA — DATE

CERTIFICATION

This project entitled "Determination of Some Physical and Mechanical Properties of Locust Bean Seeds" by Udenze Joy Chidimma 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.

-- 20/11/2006
Engr. Dr. (Mrs.) Z.D. Osunde
Project Supervisor.
Date

-- 02/11/2006
External Examiner
Date

-- 20/11/2006
Engr. Dr.(Mrs) Z. D. Osunde
Head, Department of Agricultural Engineering
Date

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DEDICATION

This project is dedicated to my dear parents, His Honour Mr. And Mrs. O.A. Udenze

ABSTRACT

Some physical and mechanical properties of locust bean seeds which is relevant to industrial applications were selected for study. The physical and mechanical properties of the locust bean seeds were established for three samples at different moisture content level of 13.2%, 16.8% and 19.5% wet basis. Standard test and experiment were used in studying the physical and mechanical properties e.g. Shape, Size, Number of seed per unit weight, Sphericity, Roundness, Geometric mean diameter, Volume and Bulk density, Colour, Force deformation, Firmness value and Toughness value. The results showed that locust bean seeds have an average major diameter of 10.68mm, Minor diameter of 4.91mm, Intermediate diameter of 7.43mm. It also has an average weight of 4.26g, volume of 5.76×10^{-7} m^3, density of 7.43×10^{-5} kg/m^3, Sphericity of 6.9×10^{-1}, Roundness of 2. 19mm, the color of the locust bean seed is black and the shape of the locust bean is elliptical. The compressive force on the locust bean seeds were evaluated as well. The results of the evaluation showed that the mean load at peak is 112.58N, and mean deflection at peak is 1.52mm, load at yield is 29.60N and mean deflection at yield is 0.12mm. The results indicate that the values of the parameter evaluated increased as the moisture content of the seeds Increase.

TABLE OF CONTENTS

	PAGE
Title page	i
Declaration	ii
Certification	iii
Dedication	iv
Acknowledgement	v
Abstract	vi
Table of content	vii
List of Figure	x
List of Tables	xi
List of Plates	xii
CHAPTER ONE	
1.0 INTRODUCTION	1
1.1 Botany	1
1.2 Harvesting	2
1.3 Uses	2
1.4 Aim And Objectives	3
1.5 Justification	4
1.6 Scope Of Study	4
CHAPTER TWO	
2.0 LITERATURE REVIEW	5
2.1 Origin And Distribution	5
2.2 Structure	5
2.3 Planting The Seed	6

TABLE OF CONTENTS

		PAGE
Title page		i
Declaration		ii
Certification		iii
Dedication		iv
Acknowledgement		v
Abstract		vi
Table of content		vii
List of Tables		ix
List of Figures		xi
List of Plates		xii
CHAPTER ONE		
1.0	INTRODUCTION	1
1.1	Botany	1
1.2	Harvesting	2
1.3	Uses	2
1.4	Aims and Objectives	3
1.5	Justification	4
1.6	Scope of study	4
CHAPTER TWO		
2.0	LITERATURE REVIEW	5
2.1	Origin and Distribution	5
2.2	Structure	5
2.3	Planting	6

2.4	Recommended Species Of Africa	6
2.5	Chemical Composition	6
2.6	Physical And Mechanical Properties	7
2.6.1	Physical Properties	8
2.6.2	Mechanical Properties	9
2.7	Processing Of Locust Bean	10
2.7.1	Traditional Processing Method Of Locust Beans	11
2.7.2	Traditional Open Sun Drying	12
2.7.3	Merits Of Drying Dadawa	12
2.7.4	Limitation Of Local Method	12
2.8	Improvement Efforts On Locust Beans Processing	12
CHAPTER THREE		
3.0	MATERIALS AND METHODS	13
3.1	Determination Of Moisture Content	13
3.2	Selected Physical Properties	13
3.2.1	Size	14
3.2.2	Shape	14
3.2.3	Seed Weight	15
3.2.4	Volume And Bulk Density	15
3.2.5	Geometric Mean Diameter	15
3.2.6	Sphericity	16
3.2.7	Roundness	16
3.2.8	Colour	17

3.3	Selected Mechanical Properties	17
3.3.1	Force Determination	17
3.3.2	Compression Test	18
3.3.3	Firmness Value (Q)	18
3.3.4	Toughness Value (T)	18
CHAPTER FOUR		
4.0	RESULTS AND DISCUSSION	19
4.1	Shape	19
4.2	Size Of Seed	19
4.2.1	Major Diameter	19
4.2.2	Minor Diameter	19
4.2.3	Intermediate Diameter	19
4.3	Weight	20
4.4	Volume And Bulk Density	20
4.5	Sphericity	20
4.6	Geometric Mean Diameter	20
4.7	Roundness	21
4.8	Colour	21
4.9	Results For The Mechanical Properties	23
4.10	Discussion Of Mechanical Properties Result	23
4.11	Limitation Of The Study	24
CHAPTER FIVE		
5.0	CONCLUSION AND RECOMMENDATIONS	25
5.1	Conclusion	33
5.2	Recommendations	33
	References	34

LIST OF TABLES

Table		Page
2.1:	Criteria for describing shape and size	8
4.2:	Results of the physical properties of locust bean seeds	22
4.3:	Longitudinal Loading of Locust bean seeds at Moisture content of 16.8%	25
4.4:	Longitudinal Loading of Locust bean seeds at Moisture content of 19.5%	26
4.5:	Axial Loading of Locust bean seeds at Moisture content of 16.8%	27
4.6:	Axial Loading of Locust bean seeds at Moisture content of 19.5%	28

LIST OF FIGURES

Figure		Page
4.1	Force Deformation curves of locust bean seeds at Longitudinal Loading at Moisture Content of 16.8%	29
4.2	Force Deformation Curves of Locust Bean seeds at Longitudinal Loading at Moisture Content of 19.5%	30
4.3	Force Deformation Curves of Locust Bean seeds at Axial Loading at Moisture Content of 16.8%	31
4.4	Force Deformation Curves of Locust Bean seeds at Axial Loading at Moisture Content of 19.5%	32

LIST OF PLATES

Plate		Page
3.1:	Diagram Showing How to Determine the Size of Locust Bean Seeds	14
3.2:	Diagram Showing How to Determine the Roundness of Locust Bean Seeds	17

CHAPTER ONE

1.0 INTRODUCTION

Locust bean biologically named Ceratonia siliqua otherwise known as carob bean is an evergreen tree native to the Mediterranean region and is probably native to the Middle East. It is related to Mesquite, Acacia and Tragacanth trees. Cultivated since antiquity in hot, semi-arid regions, serves as an important forage crop. The products of the tree, especially the powder from the pods is in widespread used both near the trees habitat and throughout the industrialized world.

1.1 BOTANY

Locust bean (or carob) belongs to the family of seeds of Ceratonia siliqua, a tree widely cultivated in the Mediterranean region.

Ceratonia siliqua (Locust bean) is a long-lived evergreen tree up to 15m tall in favourable conditions in the wild but under cultivation, it is much smaller. It displays great variation in biological form and floral types, in unfavourable habitats, it takes a shrubby form with multiple stems.

A large number of named cultivars have been developed. The size, shape and thickness of the pod containing the seeds varies greatly depending on the cultivar, but up to 18 hard, brown seeds are contained in each pod; the pod may be up to 30cm long (Grainger and Winer, 1990).

The tree thrives under the hot, dry summers and cool, wet winters of the Mediterranean climates. More recently, commercial exploitation has developed significantly in several North African countries including Morocco and Algeria. It has also been introduced to the warmer parts of the United states, Mexico, South Africa, Australia and India (Carlson, 2000).

Locust bean has a number of attributes, which make it well suited to promotion as a multipurpose tree in the drier parts of the world. It grows on a wide variety of soils, including marginal and rocky ones and requires relatively little attention. It is reasonably drought resistant, although it needs some rain if it is to yield commercial quantities of pods. (Carlson, 2000).

Yields of pods are extremely variable and depend very much on the cultivar in question as well as climatic and other conditions where the trees are growing. individual trees have been reported to yield up to 0.5-1.0 tonnes of pods. Yields increase steadily up to 25-30 years of age but may vary in alternate years, being high one year and low the next, but well cared cultivated trees have a productive life of 60-100 years. (Hills, 1994)

1.2 HARVESTING

The first commercial fruits can be harvested after about 5-7 years. After flowering, the pods takes about 6-8 months to mature, turning from green to chocolate brown in the late summer. The mature pod contains a yellow, dry, powdery pulp in which a number of dark brown or black seeds are embedded. In the raw form, the seeds are extremely hard and practically inedible. (Ikenebomeh and Kok, 1999).

They are usually harvested by knocking them off with long poles, preferably aimed at the bunches of pods themselves rather than by indiscriminate beating of the branches. The mature pods occur in large bunches. Each pod may be up to 30cm. (Carlson, 2000).

1.3 USES

The long leathery pods from the tropical carob tree contain a sweet, edible pulp (which can be eaten fresh). After drying, the pulp is roasted and ground into a powdery form, used in making liqueurs, as an ingredient in cosmetics and a flavoring in baked goods and candies. They can however, be processed and fermented to a tasty product called dadawa in West Africa. Dadawa serves as a source of protein intake among the low-income group and rural populace of West Africa (Ikenebomeh and Kok, 1999).

Grinding the pulp and pod together makes carob powder. But fresh and dried carob pods as well as carob powder may be found in health food and specially food stores.

An edible gum, Locust bean gum, a substitute for gum Tragacanth, is extracted from the seed. it is also used as a stabilizer, thickening agent, and as an egg substitute. The pods are used as an animal feed. Carob (Locust bean) is an additive in breakfast foods such as jams, marmalades and yogurts. Used in cake icing, canned poultry and meats, prepared mustard and some toothpaste. (www.zingsolutions.com, 1998).

The seed gum is employed in the manufacture of cosmetics, pharmaceutical products, detergent, paint, ink, shoe polish, adhesive, sizing for textile, photographic paper, insecticides and match heads. It is also utilized in tanning. Where rubber latex is produced, the gum is added to cause the solids to rise to the surface. It is also used for bonding paper pulp and thickening silkscreen pastes and some derivates are added to drilling mud. (www.zingsolution.com, 1998).

1.4 AIM AND OBJECTIVES

The aim of this project is to determine some of the physical and engineering properties of locust beans at different moisture content level.

The specific objectives of this project are :

- to determine some of the physical properties of locust bean seeds such as: Seed weight, roundness, geometric mean diameter, sphericity, size, shape, volume and bulk density at three moisture content level.

- to determine the mechanical properties of locust bean seeds such as: Force deformation behaviour, compression test, firmness value, and toughness value at three moisture content level.

1.5 JUSTIFICATION

Generally, some of the physical and mechanical properties of locust bean is in the design of machines and relevant facilities for handling and processing of locust bean. The size and shape are important in designing of separating, sizing and grading machines. Bulk density affect the structural loads, resistance to air flow of the stored mass and are important parameters in designing of drying and storing systems.

1.6 SCOPE OF STUDY

Some physical and mechanical properties of relevant industrial properties have been selected for study within the scope of this project.

CHAPTER TWO

2.0 LITERATURE REVIEW

The increasing economic importance of food materials together with the complexity of modern technology for their production, handling, storing processing, preservation, quality evaluation, distribution and marketing and utilization demand a better knowledge of the significant physical properties of these materials.

From the production units on the farm to the consumer food materials are subjected to various methods involving mechanical treatment, thermal treatment, electrical treatment, optical treatment and some technique and devices. It is essential to understand the physical laws governing the response of these biological materials so that the machines, processes and handling operations can be designed for maximum efficiency and the highest quality of the end products.

2.1 ORIGIN AND DISTRIBUTION

Locust bean botanically *Ceratonia siliqua* is a long-lived evergreen tree, up to 15m tall in favorable conditions in the wild, but under cultivation, it is much smaller. The size, shape and thickness of the pod containing the seeds varies greatly depending on the cultivar, but up to 18 hard, brown seeds are contained in each pod, the pod may be up to 30 cm long, (Grainger and Winer, 1990)

The tree thrives under the hot dry summer and cool, wet winters of the Mediterranean Climate and it is distributed throughout the Mediterranean region, (Carlson, 2000).

2.2 STRUCTURE

The seeds of locust bean are generally similar in structure compare to other leguminous plant. The various anatomical parts of locust bean are similar to legumes.

The outermost layer of the seed is the *testa* or seed coat. The shape of the locust bean seed is elliptical; this is compared with the shape of a chartered standard, Mohsenin, (1970). The size, shape, and thickness of the pod containing the seeds varies greatly, (IITA Ibadan, 1989).

2.3 PLANTING THE SEEDS

The seeds needed for the planting should be collected from freshly fallen pods from strong healthy trees. Viability is short so it is best to plant the seeds as soon as possible. Germination is by improved water or scalding for about 7 minutes. Seedlings raised in pot are ready for planting in the filed after 10-14 weeks. Growth rate is moderate, 22 years old tree can have a trunk diameter of about 17-20 cm, spacing 5 X 5 m, followed by thinning from 8th to 10th year, to leave a population of 500 tree/ha (Hills, 1994).

2.4 RECOMMENDED SPECIES OF AFRICA

The following locust beans species have been recommended by the food and agricultural organization, (FAO, 1998).

1. Parkia biglobosa
2. Parkia clappertoniana
3. Parkia fiilicoidea
4. Parkia bicolou

2.5 C HEMICAL COMPOSITION

Locust bean occupy a premier position as a world crop because of its high and virtually unrivaled fat content, moderate starch, minerals and vitamins. Locust bean have a good balance of then essential amino acids and are excellent dietary source of calories, minerals and vitamins, (Charalambous, 1985).

From available literature, it was discovered that locust bean have high level of lipids content. The lipid has been found to be of high nutritional value of its high content of polyunsaturated fatty acids including the essential fatty acid, and linoleic acid. The linoleic acid helps in the regulation of serum cholesterol and hence help in reducing or preventing coronary heart disease, hypelipemia and hence atherosclerosis, (Gunstone and Noris, 1983).

Natural lipids are usually mixtures of several classes of lipids and each contains a wide range of fatty acids. Generally., the fat is required for the provision of energy they travel in the blood stream from the fat depots. Protein of the liver and tissues, which act as a kind of protein store to maintain the protein level in the diet, soon leads to serious disorders. The biological material is an analytical term for the inorganic residue that remains after the organic matter present in the original food since there may be losses due to the volatilization or chemical interaction between the constituents. The value is useful in assessing the quality or grading certain edible materials (Joslyn, 1970).

2.6 PHYSICAL AND MECHANICAL PROPERTIES

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

Some of these properties that are useful in processing of locust bean seeds include:

2.6.1 PHYSICAL PROPERTIES

Shape, size, volume, surface area, density, porosity, colour and appearance are some of the physical properties which are important in many problems associated with the design of a specific machine or analysis of the behaviour of the product in handling of the material.

Size and shape are inseparable in physical object and both are generally necessary if the object is to be satisfactorily described. Criteria for describing shape and size are found in Mohsenin (1970) as shown below.

TABLE 1: CRITERIA FOR DESCRIBING SHAPE AND SIZE

SHAPE	DESCRIPTION
Round	Approaching spheroid
Oblate	Flatten at stern end in shape
Oblong	Vertical diameter greater than horizontal diameter
Conic	Tapered toward the apex
Ovate	Egg shaped and broad at 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 depart materially from a circle

SOURCE: MOHSENIN, (1970)

Shape and size is also important in problem of stress distribution in the material under load, in electrostatic separation of seeds and grains in light reflectance and color evaluation and in development of sizing and grading of machinery.

A Knowledge of density and specific gravity of agricultural products is needed in calculating thermal diffusivity in heat transfer problems in determining Reynolds number in pneumatic and hydraulic handling of the materials and in predicting physical structure and chemical composition.

Surface colour and appearance of agricultural products are valuable physical characteristics for selective separation in the field as subsequent handling of the materials and processing. In selective harvesting of fruits and vegetables and in sorting and grading at post-harvesting and during storage, desirable product can be selected on the basis of colour and appearance.

2.6.2 MECHNAICAL PROPERTIES

Mechanical damage to seeds and grains, which occur in harvesting, threshing and handling can seriously affect viability and germination power, growth vigor, insect and fungi attack and quality of the local product. Depression of viability is due to mechanical damage to the embryo of the seed. The depression of growth vigor of the damaged seed has been demonstrated by the decrease of the size of shoots and the weight of the plants.

Hardness of grains has been a subject of interest of millers, livestock feeders, breeders and other agricultural scientist. Biting or cutting the grain has provided a qualitative evaluation of grain hardness.

Mechanical properties such as compressive strength, impact and shear resistance are important and in some cases, necessary engineering data in studying size reduction of cereal, grains as well as seed resistance to cracking under harvesting and handling conditions. From an energy standpoint, this information can be used to determine the best method (shear, impact or static crushing) to break-up or grind grain).

Static and sliding co-efficient of friction of grains, forage materials and some other farm products on metals, woods and other materials are needed by design engineers for rational design and predicting-motion of the materials in harvesting and handling equipment, Mohsenin, (1970). Co-efficient of friction is also important in determining the pressure of grain and silage against bin walls and silos. Compressibility, expansion characteristics, co-efficient of internal friction and cohesion, and elasticity of forage or silage mass are important in studying compressibility of the materials and determining methods of compressing and packaging. shearing resistance and bending strength of forage crops as they are cut are also important mechanical properties for understanding the nature of the cutting process and energy requirements in mowing machines.

Mechanical harvesting, bulk density, transporting and storage of fruit and vegetable products have also indicated a need for basic information in mechanical harvested potatoes, distortion of onion bulbs in bottom of the storage pile, and mechanical damage of fruits and vegetable by compression, impact and vibration have lowered the grade of Locust bean, with consequent loss to the seeds.

2.7 PROCESSING OF LOCUST BEANS

Locust bean is very valuable and useful agricultural product. it is one of the main sources of protein, starch, fat, mineral and vitamins, which are essential to maintain good health.

The first stage involves removal of the seed hull. This is achieved either by mechanical abrasion or by chemical treatment. In one method, the seeds are roasted, which loosens the hulls and enables it to be removed from the rest of the seed; the remaining part is cracked and the crushed germ, which is more friable than the endosperm is sifted off from the unbroken halves, Singh (1986).

An alternative method is to treat the whole seed with acid at an elevated temperature: This carbonizes the hull, which is removed by washing and brushing operation, and the dried germ/endosperm is important since residual specks of it will detract from the quality and value of the final product. The pieces of endosperm are then ground to the required particle size to furnish locust beans, (Winer, 1980).

2.7.1 TRADITIONAL PROCESSING METHOD OF LOCUST BEANS

The traditional method of locust bean processing involves the roasting of the kernels mixed with small pieces of stones to prevent burning and thereafter, crushed kernels are sieved using traditional sieve which is made up of piassava outer layer and then boiled for at least 2-4 hours depending on heat process. The boiled kernels are sieved in order to remove away the pericarp of the kernels and other unwanted materials before it is stored for fermentation process. The product is stored in a round made basket using the tough grasses, which is obtained from the swampy conditioned area or land. White ashes is sprinkled on top of the product in the basket and then covered with broad leaves in order to ascertain the fermentation, which last over 2-3 days. After the fermentation, the beans are then pounded in a mortar using wooden pestle of which the beans are thoroughly compounded together to ease the mould thereby pressing with the hands to enhance the drying process.

2.7.2 TRADITIONAL OPEN SUN DRYING

Drying of processed locust beans (dadawa) has long been practiced traditionally by the local farmers, mostly in the sub-sahara northern parts of Nigeria, where there is high intensity of sunshine and low relative humidity throughout the year. In particular, traditional open sun drying of dadawa is carried out on an open flat container for easier drying.

2.7.3 MERITS OF DRYING DADAWA

Some of the merits in drying dadawa includes:

1. It allows the product to resist spoilage due to the presence of moisture
2. To keep off flies due to the distinctive odour as a result of fermentation.
3. To reduce the odour

2.7.4 LIMITATION OF THE LOCAL METHOD

The method is prone to waste during the process of kernels crushing after roasting and subsequent poor fermentation method or procedure. Most importantly, there is the problem of low nutritional constituent e.g. level of protein which is due to the broken kernels and over fermentation which produces the strong distinctive odour.

2.8 IMPROVEMENT EFFORTS ON LOCUST BEANS PROCESSING

Methods have been reported. aimed for design and improvement of relevant machines and facilities for handling, storing, harvesting and processing of locust beans. Also, at improving the nutritional contents of the processed locust beans as well as removing the kernels odour after the fermentation. The unwanted kernels odour is principally considered to be as a result of lipid oxidation catalyzed by lipoxidase enzyme, (IITA, 1989)

CHAPTER THREE

3.0 MATERIALS AND METHODS

The main material used in this study is locust beans. The locust bean was obtained from central market Minna, Niger state. Seeds (Locust beans) were cleared manually to remove all foreign matter, broken and immature seeds.

Three samples of the seeds were prepared and taken to the National Centre for Agricultural Mechanization (NCAM) Idofian, Ilorin, Kwara state for testing.

3.1 DETERMINATION OF MOISTURE CONTENT

Three bulk samples of the Locust bean seeds were each cleaned and conditioned to a different moisture content to obtain three moisture content level. Using the method of Ezeike (1986) as described by Aviara et al (2002). This involved the soaking of the bulk Locust bean seeds in hot water for a period of time, followed by spreading out in thin layer to dry in natural air for some hours and then wrapped in a foil paper to attain stable and uniform moisture content.

The three samples were then grounded using a blender and finally poured inside a grain moisture meter which the thermal printer consequently printed the moisture content values.

3.2 SELECTED PHYSICAL PROPERTIES

The physical properties of locust bean is studied by considering either bulk or individual units of the material. It is important to have an accurate estimate of shape, size, volume, weight, density, sphericity, roundness and other physical properties which may be considered as engineering parameters for the product.

3.2.1 SIZE

Three samples were used. The size of locust bean seed was determined along three principal axes of the seed (major, minor and intermediate). A digital vernier caliper with a reading accuracy of 0.01mm was used in measuring. Five replicates were used for each sample.

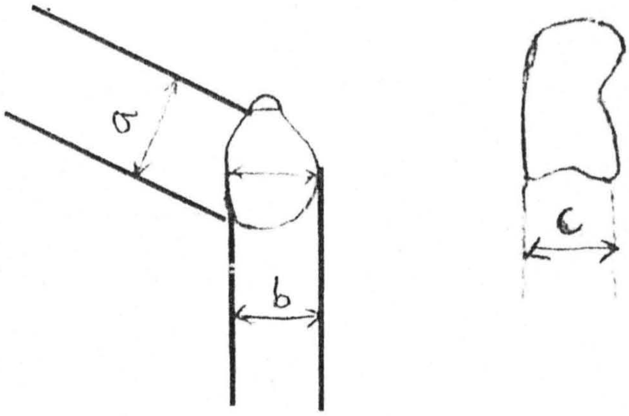

Plate 1: Diagram showing determination of size of locust bean seeds

Source: Mohsenin, (1970)

a=Major diameter

b=Intermediate diameter

c=Minor diameter

3.2.2 SHAPE

The shape of the locust bean seeds is determined by tracing the longitudinal and lateral cross section of the seed. This is compared with the shape listed on a chartered standard, Mohsenin, (1970)

Using the standard charts, descriptive terms were used to define the shape of the product over five replicate.

3.2.3 SEED WEIGHT

To obtain the 100-seed weight of the three samples, 100 seeds were randomly selected from the bulk and divided into five groups of 20 seeds each and weighed by an electronic weighing balance to an accuracy of 0.01g.

3.2.4 VOLUME AND BULK DENSITY

The bulk density of the three samples of the locust bean seeds were determined by filling a beaker of known self-weight and volume with water and noting the volume followed by pouring the known quantity of locust beans seed and noting the difference in the water level.

The bulk density was calculated from the expression

$$\text{Bulk Density } \rho_b = \frac{\text{Mass of locust beans seed}}{\text{Voliume of the container}} \quad (1)$$

3.2.5 GEOMETRIC MEAN DIAMETER

To determine the Geometric Mean Diameter (GMD) of the three samples with five replicates each of the locust bean seeds were used and the expression:

$$GMD = (abc)^{1/3} \quad (2)$$

was used in calculating it (Moshenin, 1970)..

where:

a = Major diameter

b = Intermediate diameter

c = Minor diameter

3.2.6 SPHERICITY

The geometric foundation of the concept of sphericity rests upon the isoperimetric property of a sphere.

To determine the sphericity of locust beans the values of major, Minor and intermediate diameter of the material were obtained using five replicates of the seed. The sphericity was then calculated using the formula:

$$\textit{Sphericity} \quad S = \left(\frac{b.c}{a^2}\right)^{1/3} \qquad (3)$$

(Mohsenin, 1970)

Where:

a = Major diameter

b = Intermediate diameter

c = Minor diameter

3.2.7 ROUNDNESS

To determine the roundness of the locust bean seeds, measure of the sharpness of the corners of the solid, their outlines traced on a graph paper. Five replicates were used. Ap and Ac are measured and used in equation 4 according to Mohsenin, (1970).

$$\text{Roundness} = A_p / A_c \qquad (4)$$

Where A_p = Traced area of locust beans obtained

A_c = Traced area of the smallest circumscribing circle

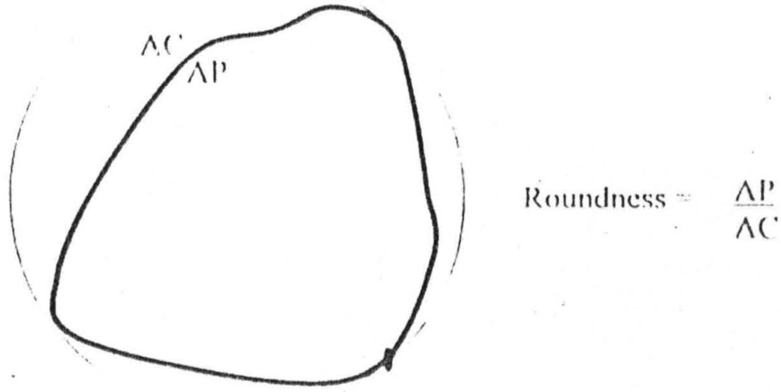

Plate2: Diagram showing determination of the roundness of locust beans

3.2.8 COLOUR OF LOCUST BEAN SEED

The colour of locust bean seed was determined by the use of natural light.

3.3.0 SELECTED MECHANICAL PROPERTIES

The mechanical properties are those having to do with the behaviour of the material under applied forces.

In an attempt to obtain more meaningful and usable data on mechanical properties of agricultural products, many investigators have approached the problem by employing testing procedure used for non-biological materials. In this section, techniques for obtaining data on force deformation, firmness value (Q), Toughness value (T) and Stress-strain data from compression tests of locust bean seeds is discussed.

3.3.1 FORCE DETERMINATION

Study of force deformation behaviour of the three samples of locust bean seeds at three different moisture content level has been an attempt to provide objective measurement resulting in more meaningful data usuable in engineering analysis and design

3.3.2 COMPRESSION TEST

The test was conducted using a Universal Testing machine. The machine was used to compress the materials to obtain values for stress and strain. The seeds were compressed at a rate of 2.25mm/min. the seeds were loaded and compressed at the natural position at rest. The testing machine was controlled by a microcomputer, which allowed the user to control the speed and direction of the compression plate, and to automatically collect the data

3.3.3 FIRMNESS VALUE (Q)

The value is defined as the slope of the linear force deformation curve i.e. F/D. Peak force (F) were taken as the force at the point of rupture.

Deformation (D) was defined as the distance of the cross head travel from the first contact with the locust bean surface under testing to the point rupture.

$$\text{Firmness value (Q)} = \frac{F}{D} \qquad (5)$$

Where: F = Force at the rupture

D = Deformation

3.3.4 TOUGHNESS VALUE (T)

The seed toughness is defined as the total energy absorbed up to the point as given by the area under the force-deformation curve.

The formula for a right triangle was used in calculating the value.

$$T = 1/2FD \qquad (6)$$

Where: T = Toughness

F = The peak force N (bio-yield)

D = Deformation (mm)

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

Data obtained from the experiment and test is given in table 3. These results are the main values obtained over five replicates of the seeds to obtain the selected physical and mechanical properties at a moisture content of 13.2%, 16.8% and 19.5%.

4.1 SHAPE

The shape of the locust bean seed as defined by the standard chart are in table 3. The moisture content has no effect on the shape of the locust bean because of the hardness of the seed.

4.2 SIZE OF SEED

The highlight of these results and discussion are the major, minor and the intermediate diameters.

4.2.1 MAJOR DIAMETER

The results on table 3 shows that the three samples of they locust bean seeds for this study has overall average value of diameters of 10.68mm, 11.09mm and 11.05mm. The moisture didn't affect it much because of the irregularity of the seeds.

4.2.2 MINOR DIAMETER

The overall mean value of the minor diameters of three samples of the locust bean seeds are 4.91mm, 6.24mm and 4.97mm. The irregularity in the seeds made the moisture content not to have visible effect on the minor diameter.

4.2.3 INTERMEDIATE DIAMETER

The overall mean value of the intermediate diameters of three samples of the locust bean seeds are 7.43mm, 8.48mm and 8.36mm. The irregularity in the seeds made the moisture content not to have a visible effect on the intermediate diameter.

4.3 WEIGHT

The mean overall weights of the locust bean seeds for this study are 4.62g, 4.38g and 4.47g. As the moisture content increases the seed weight increases then reduces and finally increase. This is as a result of the irregularity in the seed. Moreover, the seeds were selected at random.

4.4 VOLUME AND BULK DENSITY

The mean volume of the material which is equal to the volume of the displaced water are $5.78 \times 10^{-7}m^3$, $7.60 \times 10^{-7}m^3$ and $10.60 \times 10^{-7}m^3$. The density of the locust bean seeds which is mass per volume are $7.43 \times 10^{-5}kg/m^3$ and $4.21 \times 10^{-5}kg/m^3$. From these results, it is been deduced that as the moisture content increases, the volume and bulk density increases.

4.5 SPHERICITY

The results for this study is shown in table 3 and are 6.9×10^{-1}, 7.32×10^{-1}, and 6.94×10^{-1}. The moisture content has no much effect on the sphericity because of the irregularity of the seeds.

4.6 GEOMETRIC MEAN DIAMETER

The result for the GMD for this study is shown in the table 2. The seeds irregularity made the moisture content of the seed not to have a visible effect on the GMD.

4.7 ROUNDNESS

The result obtained for the roundness in the three samples of the locust bean seeds for this study are 2.19, 2.04 and 2.27. The moisture content does not have much effect on the roundness of the locust bean seed because of the irregularity of the seed.

The results obtained from this study is shown in table 3. The Moisture content of the locust bean has no effect on the colour of the seed.

4.8 COLOUR

The result obtained from this study is shown in table 2. The moisture content of the Locust bean has no effect on the colour of the seed.

TABLE 2: RESULTS OF THE PHYSICAL PROPERTIES OF LOCUST BEAN

S/No.	PROPERTIES	MEAN VALUE OF LOCUST BEAN SEEDS AT M.C OF 13.2%	MEAN VALUE OF LOCUST BEAN SEED AT M.C OF 16.8%	MEAN VALUEOF LOCUST BEAN SEED AT M.C OF 19.5%
1.	Shape	Elliptical	Elliptical	Elliptical
2.	Size (mm)			
	a) Major diameter	10.68	11.05	11.05
	b) Minor diameter	4.91	6.24	4.97
	c) Intermediate diameter	7.43	8.48	8.36
3.	Weight (g)	4.26	4.38	4.47
4.	Volume (m^3)	$5.76 X 10^{-7}$	$7.60 X 10^{-7}$	$10.60 X 10^{-5}$
5.	Density (kg/m^3)	$7.39 X 10^{-6}$	$7.39 X 10^{-6}$	$7.39 X 10^{-6}$
6.	Sphericity	$6.9 X 10^{-1}$	$7.32 X 10^{-1}$	$6.94 X 10^{-1}$
7.	Roundness	2.19	2.04	2.27
8.	GMD (mm)	7.17	8.08	7.50
9.	Colour	Black	Black	Black

4.9 RESULTS FOR THE MECHANICAL PROPERTIES

The result of the Compressive Test carried out on the Computerized Universal Testing machine for the locust bean seeds at different moisture content levels to determine some of their mechanical properties are given in Tables 4.3 to 4.6.

The samples were subjected to mechanical testing under compressive loading. Two loading orientations were used: Longitudinal and Axial (along the cleavage and across the cleavage) with five replications on each loading.

Tables 4. 3 and 4.4 show the longitudinal loading of the samples of the locust bean seed. Tables 4.5 and 4.6 show the axial loading of the locust bean seeds at different moisture content.

Figs 4.1 to 4.4 are force deformation curves obtained from the compression test (both longitudinal loading and axial loading) of the locust bean seeds at different moisture content.

4.10 DISCUSSION OF MECHANICAL PROPERTIES RESULT

The result obtained from the compression test for the longitudinal loading at moisture content of 16.8% and 19.5% shows that the minimum values obtained decreases as the moisture content increases, (Tables 4.3 and 4.4).

The mean results at longitudinal loading at moisture content of 16.8% and 19.5% show that the moisture contents affect the mean results because the results increases more at moisture content of 19.5% which is an indication of the force per unit area on the seed that is sufficient to cause cell rupture of the seed, (Tables 4.3 and 4.4).

The maximum values at longitudinal loading of the locust beans seeds at moisture content of 16.8% and 19.5% also show that values obtained increases with the moisture content, (Tables 4.3 and 4.4).

For the axial loading, the minimum results for the locust bean seeds at moisture content of 16.8% and 19.5% show that the values obtained decreases as the moisture content increases, (Tables 4.5 and 4.6).

The result obtained for the mean values at the axial loading at moisture content of 16.8% and 19.5% indicates that the values increases with the moisture content, (Tables 4.5 and 4.6).

The force deformation curves of the locus bean seeds at different moisture content level responded in a similar way under compressive loads. The two major identifiable points on stress-deformation curves are load and deflection.

4.11 LIMITATION OF THE STUDY

During the determination of the engineering properties of locust bean seeds, the major problem encountered was the epileptic power supply at NCAM, which impeded the speed of this work.

TABLE 3: LONGITUDINAL LOADING OF LOCUST BEANS AT MOISTURE CONTENT LEVEL OF 16.8%

Sample	Load at peak (N)	Load at yield (N)	Strain at peak (%)	Strain at yield (%)	Def. at peak (mm)	Def. at peak (mm)
R1	63.8000	13.800	17.7510	1.0622	1.8550	0.1110
R2	158.2000	32.1000	30.3050	1.9512	2.9820	0.1920
R3	186.9000	45.5000	5.2850	0.7608	0.5280	0.0760
R4	78.2000	21.3000	14.4610	1.2439	1.4880	0.1280
R5	83.8000	35.3000	6.6200	0.8014	0.7600	0.0920
Min	63.8000	13.8000	5.2850	0.7608	0.5280	0.1198
Mean	112.5800	29.6000	14.8840	1.1639	1.5226	0.1198
Max	186.9000	45.5000	30.3050	1.9512	2.9820	0.1920

TABLE 4: LONGITUDINAL LOADING OF LOCUST BEANS AT MOISTURE CONTENT LEVEL OF 19.5%

Sample	Load at peak (N)	Load at yield (N)	Strain at peak (%)	Strain at yield (%)	Def. at peak (mm)	Def. at peak (mm)
R1	64.5000	13.0000	34.0490	12.9290	4.0110	1.5230
R2	150.0000	112.3000	4.8660	12.9830	0.5090	0.3120
R3	86.3000	74.6000	3.2160	2.3990	0.3740	0.2790
R4	45.7000	29.7000	4.2340	1.0020	0.4480	0.1060
R5	283.4000	48.6000	40.5910	7.0670	3.9170	0.6820
Min	45.7000	13.0000	3.2160	1.0020	0.3740	0.1060
Mean	116.9800	55.64000	17.3910	5.2760	1.8518	0.5804
Max	238.4000	112.3000	40.5910	12.9290	4.0110	1.5230

TABLE 5: AXIAL LOADING OF LOCUST BEANS AT MOISTURE CONTENT LEVEL OF 16.8%

Sample	Load at peak (N)	Load at yield (N)	Strain at peak (%)	Strain at yield (%)	Def. at peak (mm)	Def. at peak (mm)
R1	291.2000	172.2000	11.3410	5.5820	0.5160	0.2540
R2	227.9000	50.8000	24.8030	7.0770	1.0690	0.3050
R3	166.7000	166.7000	5.0460	5.0460	0.2180	0.2180
R4	163.4000	34.9000	22.8370	5.4690	1.1190	0.2680
R5	541.4000	126.7000	32.2540	16.1490	1.4740	0.7380
Min	163.4000	34.9000	5.0460	5.0460	0.2180	0.2180
Mean	278.1200	110.2600	19.256	7.8650	0.8792	0.3566
Max	541.4000	172.2000	32.2540	16.1490	1.4740	0.7380

TABLE 6: AXIAL LOADING OF LOCUST BEANS AT MOISTURE CONTENT LEVEL OF 19.5%

Sample	Load at peak (N)	Load at yield (N)	Strain at peak (%)	Strain at yield (%)	Def. at peak (mm)	Def. at peak (mm)
R1	376.1000	79.8000	23.4070	8.9310	1.1610	0.4430
R2	162.0000	33.1000	26.5500	7.8720	1.2850	0.3810
R3	384.10000	384.1000	23.9230	23.9230	0.9880	0.9880
R4	586.8000	493.3000	8.4240	7.9060	0.3420	0.3210
R5	136.4000	27.6000	8.4240	4.9200	0.0130	0.2470
Min	136.4000	27.6000	8.4240	4.9200	0.3420	0.2470
Mean	313.0800	203.5800	20.4960	10.7110	0.9578	0.4760
Max	506.8000	493.3000	26.5500	23.9230	1.2850	0.9880

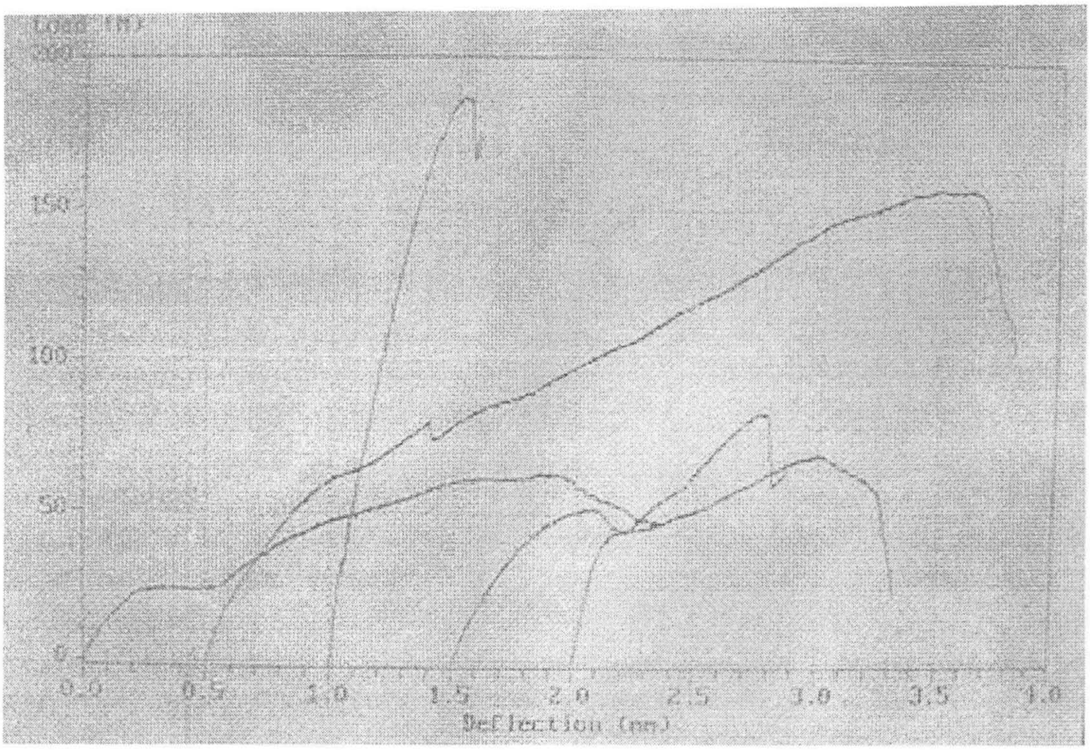

Fig 4.1: FORCE DEFORMATION CURVES OF LOCUST BEAN SEEDS AT LONGITUDINAL LOADING AT MOISTURE CONTENT LEVEL OF 16.8%

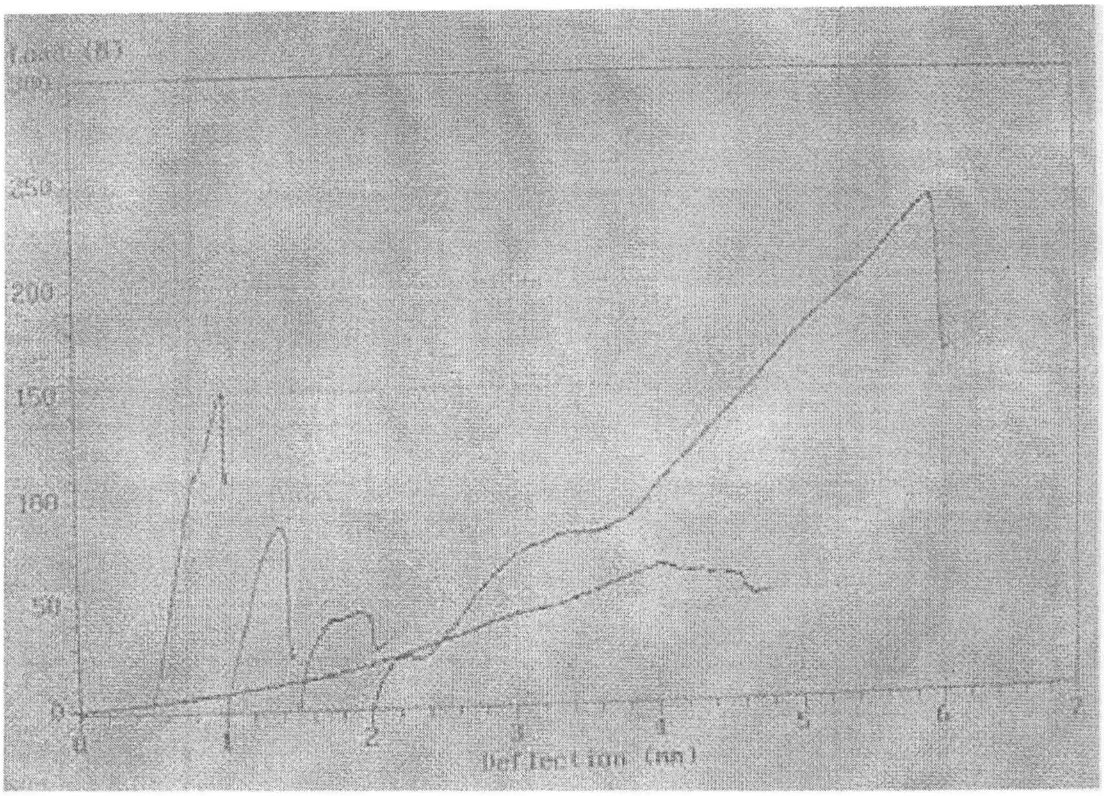

Fig 4.2: FORCE DEFORMATION CURVES OF LOCUST BEAN SEEDS AT LONGITUDINAL LOADING AT MOISTURE CONTENT LEVEL OF 19.5%

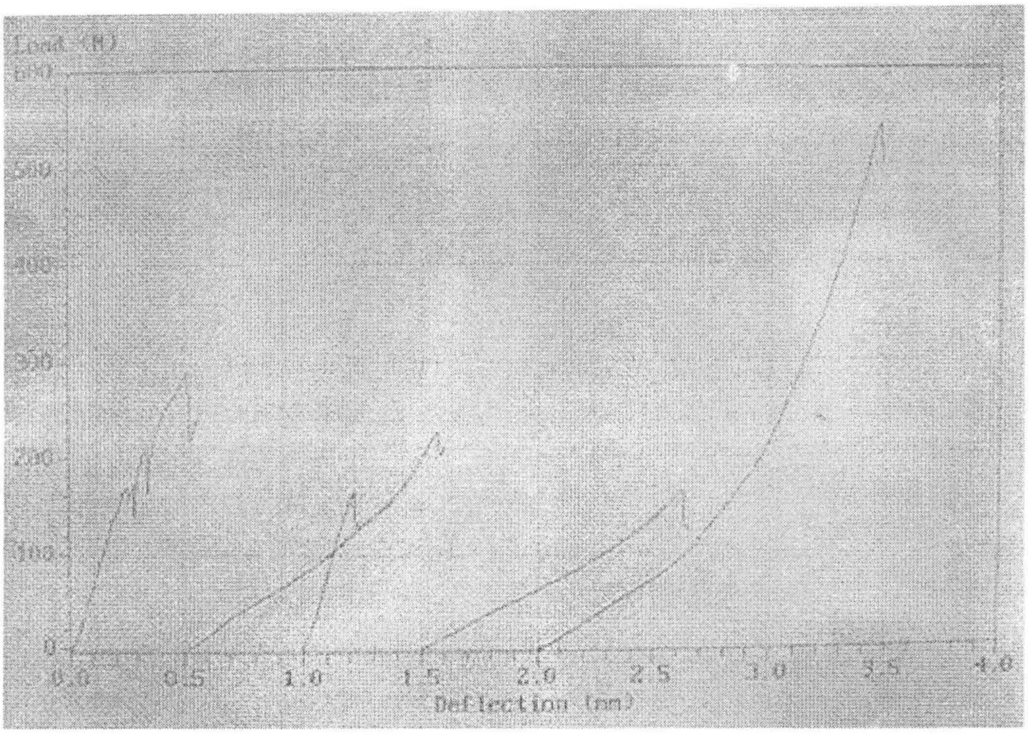

Fig 4.3: FORCE DEFORMATION CURVES OF LOCUST BEAN SEEDS AT MOISTURE CONTENT LEVEL OF 16.8%

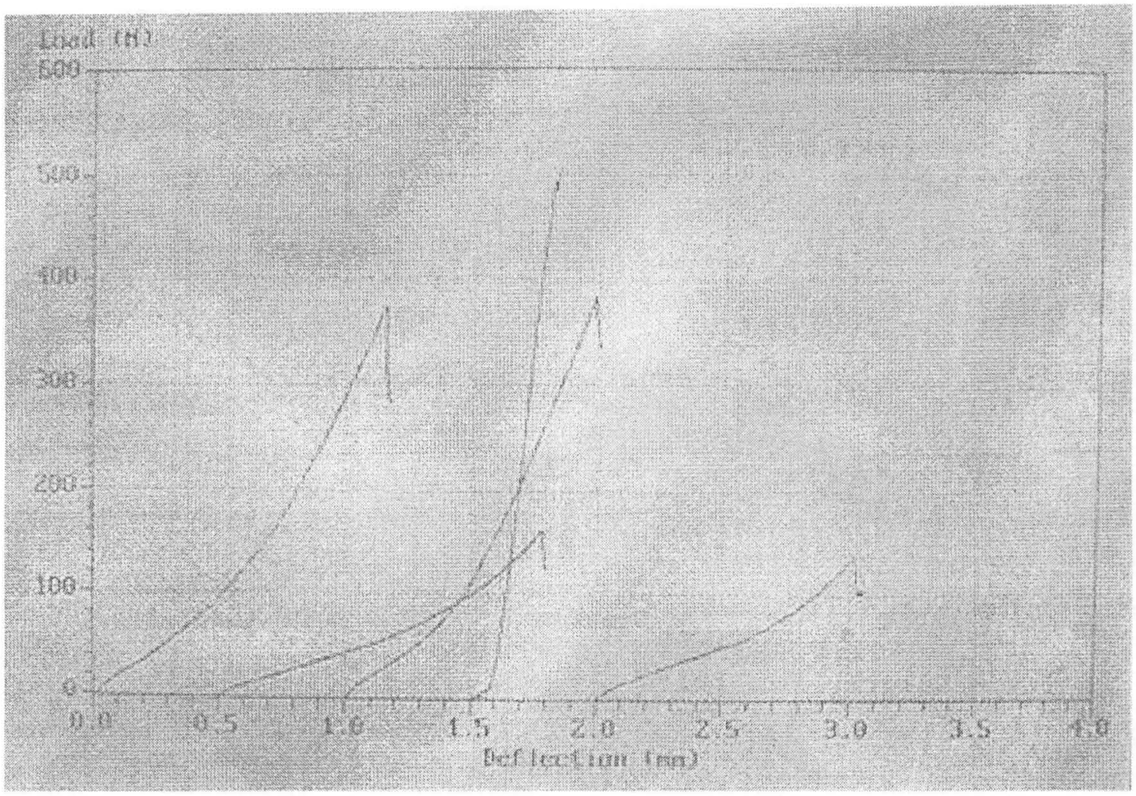

Fig 4.4: FORCE DEFORMATION CURVES OF LOCUST BEAN SEEDS AT AXIAL LOADING AT MOISTURE CONTENT LEVEL OF 19.5%

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

The determination of the physical and mechanical properties of Locust bean seeds was carried out to aid the design of machines, for storage and processing of the locust bean seeds.

Some of the physical and mechanical properties determined include size, shape, seed-weight, roundness, bulk density, GMD, colour, sphericity, force deformation, firmness value and toughness value. The aim is for a better machine design and operation through a detailed quantitative and qualitative understanding of the peculiar factors involved in machine design.

5.2 RECOMMENDATIONS

With the current trend of promoting local content in the products manufactured in Nigeria, I recommend that more research work should be carried out on Locust bean seeds to provide a suitable machine for the processing.

I recommend that the school authority through the department of Agricultural Engineering sensitize industrialist on the benefits of Locust bean in manufacturing.

I recommend that the department of Agricultural Engineering should procure a standard equipment to enable students carry out their experimental work in the laboratories.

I also recommend that the department of Agricultural Engineering should provide current journals and periodicals which can be accessible to the students in carrying out research work.

Furthermore, I recommend that the old equipment in the Agricultural Engineering laboratory be replaced with digital ones.

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