DETERMINATION OF SOME PHYSICAL AND MECHANICAL PROPERTIES OF MORINGA SEED (*Moringa Oleifera*)

BY

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MATRIC No. 2005/21548EA

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EDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

FEBRUARY, 2010

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BEING A FINAL YEAR PROJECT REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF BACHELOR OF ENGINEERING (B.ENG.) DEGREE IN AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGER STATE

FEBRUARY, 2010

DECLARATION

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

17/2/2010

Anigilaje, Habeeb Kunle   Date

CERTIFICATION

This project entitled "Determination of Some Physical and Mechanical Properties of Moringa Seed (*Moringa Oleifera*)" by Anigilaje Habeeb Kunle, 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.

17/02/10

Engr. Dr. A.A. Balami — Date

Supervisor

17/02/10

Engr. Dr. A.A. Balami — Date

HOD, Agricultural and Bioresources Engineering

10/2/2010

External Examiner — Date

DEDICATION

This project work is dedicated to Alimighty Allah and my Parents.

ACKNOWLEDGEMENTS

I give thanks to Almighty Allah the true God of the world for his mercy and favour upon me throughout this programme. I appreciate my supervisor in person of Engr. Dr.A.A. Balami for giving me part of his time to attend to me and also for the fatherly assistance given to me during the project.

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ABSTRACT

This study was carried out to determine some physical and mechanical properties of moringa seed at moisture content of 5.86% (dry basis). The average of each of the three principal diameter, geometric mean diameter and weight were 8.38mm, 7.06mm, 5.66mm, 6.92mm and 0.25g while the standard deviation and coefficient of variation were 0.70, 0.83, 0.82, 0.62, 0.06 and 0.08, 0.12,0.15, 0.09 and 0.24 respectively. The average values for seed volume, sphericity and surface area were 22.57mm^3, 82.85% and 151.87mm^3 while the standard deviation and coefficient of variation were 4.4, 6.67, 26.33and 0.2, 0.08, 0.17 respectively. The shape and density were determined to be approaching spheroid and 10.96g/cm^3 while the standard deviation and coefficient of variation for density were 1.48 and 0.14 respectively. The average static coefficient of friction on galvanized sheet, plywood and glass were 0.40, 0.33, and 0.20 while the standard deviation and coefficient of variation were 0.013,0.001,0.001 and 0.005,0.003,0.0 respectively. The average values for hardness, rupture force, cracking force and breaking force were 26N, 38.2N, 53.2N, and 68N while the standard deviation and coefficient of variation were 0.63,2.56,2.93,7.04 and 0.02,0.07,0.06,0.10 respectively. The data generated can be used in designing equipment and machines for harvesting, handling and processing moringa seed.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Moringa (*moringa Oleifera*) is a multipurpose tree having promising potential for it nutritional, medicinal and water purification benefits among others. The moringsa Oleifera seed is the major product of moringa tree and its uses cannot be over emphasized. In African countries like Nigeria and Sudan different parts of moringa are used for various purposes and the seeds of moringa have been used for various purpose such as oil extraction, water purification and food. Therefore, to exploit these great potentials of moringa seed there is the need for the seed to be properly taken care of during handling, storage and design of machineries for processing the seed to suit different purposes.

In 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 weight and size 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, 2002).

1.2 The Description of Moringa Oleifera

Moringa Oleifera is one of the fast growing tree crops in agricultural production. It is known to be adapted to an arid sandy condition and thrives very well in subtropical and tropical climates. The crop is short, slender, deciduous, perennial tree about 10m tall with drooping branches that are brittle together with the stem, the bark is corky and the leaves are feathery. The species is characterized by its long drumstick (about 30-60cm long and 2-3cm wide) shaped pods that contain seeds that are enclosed in a brown triangular softened coats and wings which split lengthwise into three parts when dry. The seeds are dark brown with three papery wings and embedded in the pith of the pod which tapering at both ends containing up to twenty seeds. The roots are thick and deeply launched in the soil.

Previous studies on *moringa oleifera* revealed that virtually every part of the tree is beneficial where people have direct dependence on tree crops and animals for their livelihood. Moringa can be grown in a nursery before it is transplanted. It could be cultivated through the dry tropical and moist zones. It can grow under an annual precipitation of 4.8 to 40.3dm^3, annual temperature of 18.7 to 28.5^{0}c and pH of 4.5 to 8, it excellent performance on sandy soil makes it to be drought resistance, it also tolerate. bacteria, fungi, laterite and sand, this makes flowering and fruiting to be freely and continuously produced. The plant is being propagated by planting limb cuttings 1-2cm long and it starts bearing pods 6-8 months after planting, meanwhile constant and regular bearing of seeds commenced after the second year and bears the pods for several years. Moringa oleifera is also known as horse radish or drumstick which be long to the moringaceae family. The moringaceae is a single genius family with 14 known species and it is planted in whole tropical belt (Oliver, 1968).

1.3 Statement of Problem

Over the years, owing to the high rate of production and lack of awareness of the benefits of moringa seed, the palnt has suffered negligence which result in wastage. Due to the increasing awareness of moringa seed the seeds have been used for different purposes which require the seed of moringa to undergo some technological processes.

1.4 Objectives

The objectives of this work are to determine some physical and mechanical properties of moringa seed which are of relevant industrial properties.

1.5 Justification

There are little or no data on the physical and mechanical properties of moringa seed in Nigeria. In order to design machines to process moringa seed there is the need provide objective measurement resulting in a more meaningful data in engineering analysis and design.

1.6 Scope

Some of the physical and mechanical properties which are of relevant industrial properties have been selected for study within the scope of this project. (colour, shape, size, weight, moisture content, sphericity, surface area, geometric mean diameter, volume, density, coefficient of friction, hardness, rupture force, crack and breakage force).

CHAPTER TWO

2.0 LITERATURE

Moringa Olaifera also known as horse-raddish or drumstick is a medium sized tree which could be about 10m high. It belongs to the moringaceas family. The moringacea is a single genius family with fourteen (14) known species and planted in the whole tropical belt (Oliver, 1986). Moringa is very common and cheap in northern part of Nigeria.

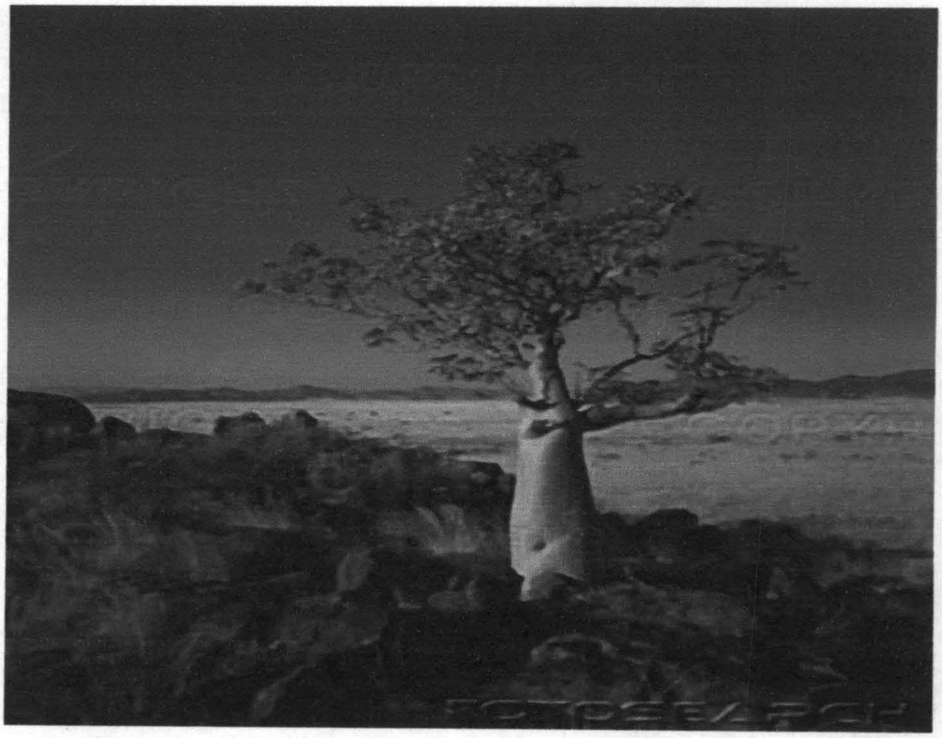

Plate 2.1. Moringa Tree.

. The popular name of moringa in Nigeria is "ZOGALE" it is known as "EWE IGBALE" "IDAGBA MANOYE" in southern Nigeria and known as "ODUDU OYINBO" in the eastern part of Nigeria.

The tree is indigenous to northern Indian and Pakistan, it is commonly known as the horse-radosh tree, arising from the use of root by Europeans in Indian as a substitute for horse-raddish is cochlearia armoracia (synonym Armoracia Russticana). Like C. Armoracia, the roots of moringa are pugent and were commonly used as condiment or when garnished it has been shown to contain 0.0105% alkaloids especially moringinine and bactericide, spirochire both of which can prove total following ingestion (Oliver, 1986).

The other widely used is the drumstick tree arising from the shape of the pods, resembling the slender and curved stick used for beating drum. Another name for moringa oleifera in Malaga is moringo and is origin of the generic name. However, very little is known about it introduction in Zimbabwe prior to its first collection by Holland in 1943. The early herbarium specimen document it as an ornamental tree. It is also grown by Indian as a vegetable but it has become a permanent feature on the menu of some African countries now e.g Nigeria with its leaves being used as a spice when preparing food. Moringa oleifera might have been introduced during the European occupation or possibly long before Arab traders (Oliver, 1986).

Moringa oleifera seed is known to be the major product of the moringa oleifera which belongs to the class of moringaceae which is a single genius family of the magnoliposida with 14 known species including the moringa oleifera that is most widely known and utilized (Morton, 1991). Moringa oleifera has required a great amount of attention as a natural nutrition of the tropic The leaves, fruits, flowers and immature pods of this tree are locally used as vegetables (Anwar, 2003). The slender pods are cooked and used in culinary preparations. The fresh beans after roasting make a potable dish. The leaves of moringa oleifera are known to be a good source of protein, vitamin A, B, and **C,** it contains minerals like calcium and iron.

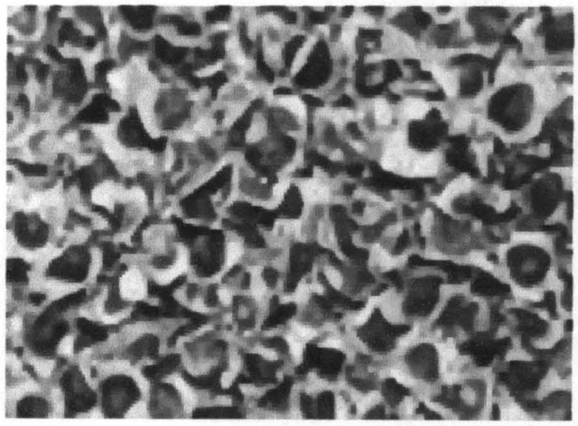

Plate 2.2 Moringa seeds with seed coat

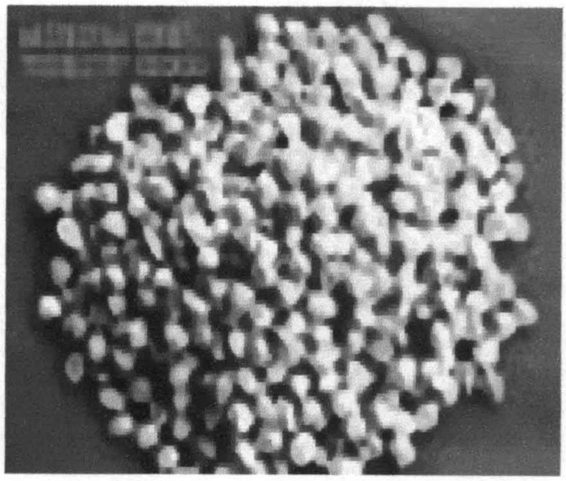

Plate 2.3 Moringa without seed coat

Moringa oleifera seeds have anti microbial activities and are utilized for water treatment. In Sudan dry moringa oleifera seeds are used in place of alum by rural women to purify the highly turbid Nile water (Muyibi and Evison, 1996). The seeds are reported to taste like peanut when fried. Moringa seeds contain oil that is commercially known as Ben oil or Behn oil has been reported to be used by watch maker for lubrication of delicate mechanism and also for illumination. The oil was also erroneously reported to be resistant to rancidity and used extensively in the process of effleurage (a process of extracting perfume by expressing absorbent to the exhalation of flowers) (Somali, 1984).

2.1 Properties of Moringa Seed

Moringa oleifera seeds are known to be encoated and lined within containing up to 20 seeds The seed kernel is said to be made up of 70-74% and contains 4.08g of water per 100g of seeds, also is the content of crude protein which is known to be 38.4g, 34.7% of fatty oil, 3.5g of fibre and 3.2g of ash. The seed oil contain 9.3% palmatic acid, 7.4% stearic acid, 8.6% of behenric acids. Recently myristic and linonelic acids have also been reported that the oil concentration varied from 25-40% depending on different extraction method i.e the method of extraction used also determine the actual amount of oil recoverable from the seed. The oil was found to contain up to 75% of oleic acid among all the earlier stated fatty acid (Ibrahim, 1974).

It was claimed that the ben seed oil content and its properties show a wide variation depending mainly on species and environmental conditions.

2.2 Benefits of Moringa Oleifera

The benefit of moringa oleifera are almost too numerous to mention, however, it is believed to be the most important and useful in extreme situations, like drought condition in arid regions or area in the wet tropics experiencing rapid rate of deforestation. Moringa is known to have solved many problems in some African countries which include Tanzania, Nicaragua, Malawi, Niger, Nigeria and Senegal. Hence, problems solved include provision of food during dry season, provision of food for animals, provide substitute for firewood, improve nutrition and purifying water to name a few. The cultivation of moringa can as well be integrated into agro forestry system to raise the quality of life even just a little (Folkard and Sutherland, 1996).

2.3 Uses of Moringa Oleifera

Almost every part of moringa oleifera plant is of value for food nevertheless, moringa was found to be used for the following purposes, vegetable, medicine, as a source of oil and as an ornament. Other non common uses include firewood, coagulants, fencing, in construction of traditional hut, making rope and as fodder for livestock's as shown in fig 1.

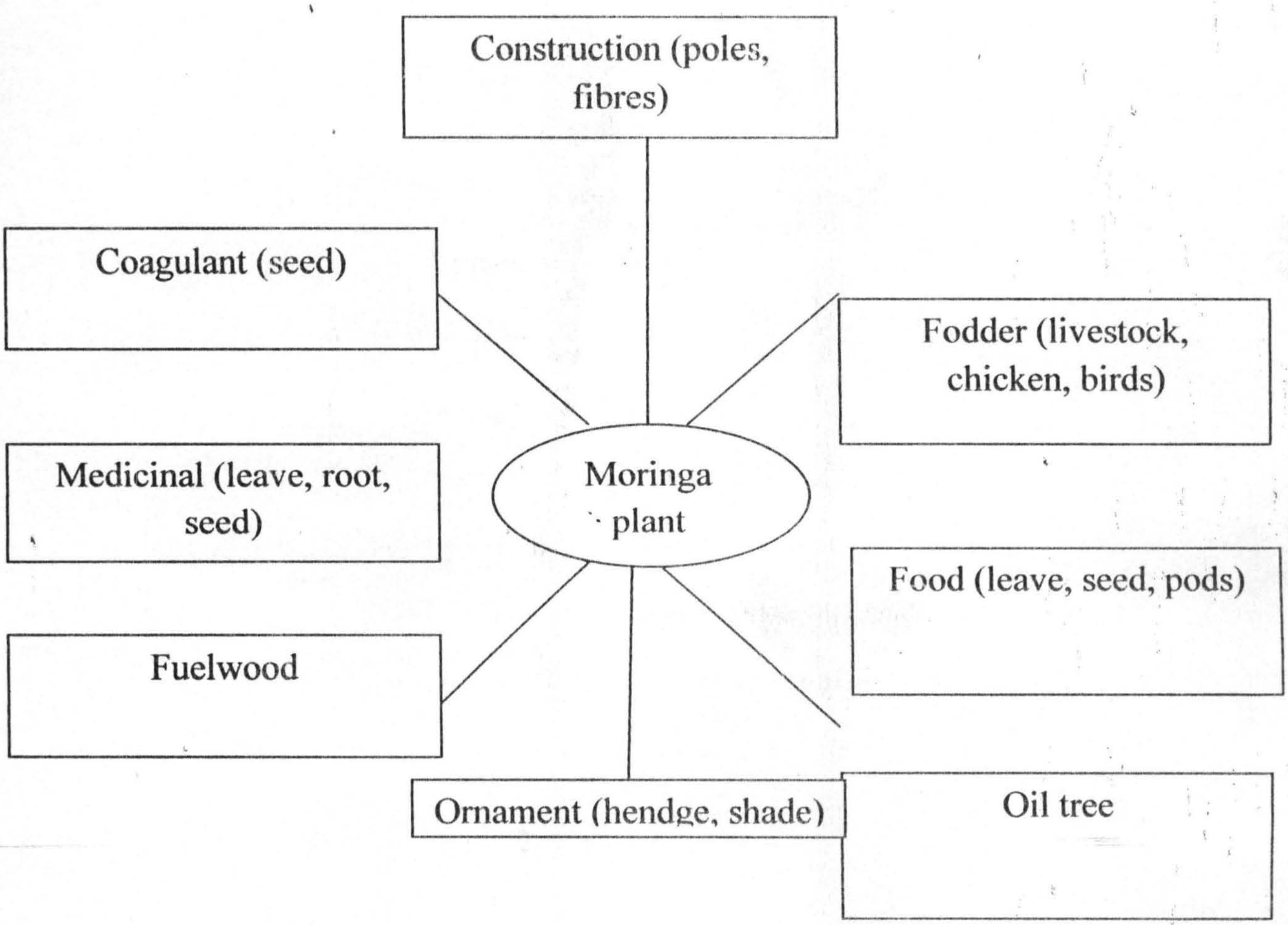

Fig 2.1 Moringa plant and its uses

2.3.1 Use of Moringa as Vegetable

Most sources seem to agree on the excellent nutritional benefits of moringa as the tree produces leaves during dry season and during the time of drought, it is an excellent source of green vegetable when little of other food is available as recorded by (Folkard and Sutherland, (1996). The leaves are widely eaten like rape or spinach in many part of Africa. It provides many necessary vitamins and minerals and can be eaten, cooked or dried. It also contains some amount of protein and the foliage can as well be eaten as green leave in vegetable curries, it can also be used as pickles and for seasoning.

The foliage has been compared to spinach in both its appearance and nutritional quality, however, as stated by Optima Africa Limited, a group working with tree in Tanzania that 25 grams daily allowance of moringa leaf powder will give a child a daily allowance of 42% protein, 125% of calcium, 61% of magnesium, 41% of potassium, 71% of iron, 272% of vitamin A and 22% of vitamin C. The leaves and branches may also be used for fodder when nothing else is useable and the high content of the leaves would make it a prime candidate to incorporate into a mulching system.

In addition to the leaves, the young pod and the domestic are of great commercial product generally prepared in a similar fashion to green beans and they are highly nutritious containing all the essential amino acids as shown in table 2.1 Nevertheless, the leaves and the young branches of moringa tree are relished by livestock, thereby providing a source of food for animal as well.

Table 2.1 Composition of leaves and pods per (100g) of moringa tree

Content	Leaves	Pods
Moisture (%)	7.5	86.9
Fat (g)	6.7	2.5
Carbohydrate (g)	1.7	0
Protein (g)	13.4	3.7
Phosphorous (mg)	2.3	2.0
Mineral matter (g)	0.9	4.8
Fibre (g)	440	30
Calcium (mg)	70	110
Todiune (mg/kg)	1.1	3.1
Iron (mg)	51	18
Vitamin A (I.U)	7.0	5.3
Nicotinic acid (mg)	11300	184
Vitamin C (mg)	0.8	0.2
Vitamin B (mg)	220	120
Moisture (%)	210	-

Source : (Council of Scientific and Industrial Research, 1962).

2.3.2 Medicinal Uses of Moringa

According to hartwell (1971), the flowers, leaves, and roots of moringa are used as remedy for several ailment, most especially for ailment, ~~most especially for~~ tumors. The seeds are used for abdominal and are also effective against skin infecting bacterial such as Staphylococus, Aureus and Pseudomonas Aerugrosa, (Oliver, 1986). Their root decotion is used in Nicaragna for dropsy. The Tonga people of Binga district in Zimbabwe used the root powder as an aphrodisiac and when it is mixed with milk it is considered useful against asthma, rheumatism and enlarged spleen or liver. It also helps in the removal of wind from the stomach and as a snuff can be used to alleviate ear and tooth ache. The root juice is applied externally as rebufacient or counter irritant. The leaves are applied as poultice to sores and can be rubbed on the temples for headache and purgative properties. The bark leaves and roots are acrid and pugent which make them to be taken and aid digestion. The leave juice has a stabilizing effect on blood pressure and can also be applied to control glucose level in a diabetic patient. Fresh leave and leave powder are also recommended for tuberculosis treatment due to the availability of vitamin A that boosts the immune system, sometimes, "the juice from the leave may be used as diuretic to increase urine flow and cures gonorrhea (Oliver, 1986). Leave juice mixed with honey also treats diarrhea, dysentery and colitis (i.e colon inflammation). Fresh leaves are as well recommended for pregnant and lactating mother in order to improve their milk production.

The bark has been regarded as an. antiscorb and exudes a reddish gum with properties of tragacanth sometimes used for diarrhea. The paste made from the ground bark can be applied to relief pain caused by snake, scorpion and insect bites. Moreso, the roots are bitter thus makes them act as a tonic to the body and lungs and are emmenegogue expectorant, mild diuretic and stimulant in paralytic afflictions, epilepsy and hysteria. The flowers are used to cure inflammation and the pods are used for joint pains, meanwhile the oil delivered from the seed is sometimes applied externally for skin diseases.

2.3.3 Use of Moringa as a Source of Oil

Moringa seeds yield about 33-40% as a non-drying and known in the trade as Ben oil. It is edible and useful in the manufacturing of perfumes and hair dressing. The oil is a clear, sweet, odourless, never rancid and edible. Because of its resistance to rancidity, it is therefore considered particularly suitable for effleurage. It is highly adored by perfumers for its great power of absorbing or retaining even the most fugitive odours. The oil is also useful in the manufacture of soap, for producing a stable lather with high washing efficiency. Nevertheless, the seed cake remains has been used as fertilizer and also as potential animal feed as it contains alkaloid and saponin. The oil is as well good for lightening illumination due to its non-drying properties (Somali, 1984).

2.3.4 Use of Moringa as Animal Feed

The leaves of moringa oleifera are readily eaten by cattle, sheep, goat, pig and rabbits. The branches are as well occasionally looped for feeding cattle. The chicken and other birds usually feed on moringa seed while fish and the later feed on the leaves (Ben Salem, 2000).

2.3.5 Use of Moringa Seed for Water Purification (Coagulant)

In addition to food, shelter and clothing, water is one of our basic need and lack of potable water is a major cause of death and disease in our world. Using natural materials to clarify water is a technique that have been practiced for centuries and of all the materials that have been used, seeds of moringa have been found to be one of the most effective. Studies confirmed that the seeds are highly effective in removing suspended particles from water with medium to high level of turbidity (Muyibi and Evison, 1996).

Moringa oleifera seeds treat water on two levels, acting both as a coagulant and as an antimicrobial agent. It is generally accepted that moringa works as a coagulant due to the positively charged, water soluble proteins, which bind with negatively charged particles (silt, clay, bacteria, toxins e.t.c) allowing the resulting "flocs" to settle to the bottom or be removed by filtration. The antimicrobial aspects of moringa continue to be researched, while there is ongoing research being conducted on the nature and characteristics of these components, it is accepted that treatment with moringa solutions will remove 90-99.9% of the impurities in water. However, moringa seeds kg been compared to alum in its effectiveness in removing suspended solids from turbid water but with a major advantage of being produced locally. More so, using moringa rather than alum would save foreign exchange and generate employment opportunities.

2.4 Growing Moringa

2.4.1 Growing Moringa for Personal Use

Moringa is an ideal plant to grow indoors or in the backyard, this is a common practice in the Philippines. One can pick it leaves and make it part of a delicious fresh salad, use it in one of our many moringa recipe. One can also dry the leaves to make a delicious green tea. One can also make tea with the leave powder in a traditional coffee maker.The moringa leave powder can be used in concentrated nutrition to balance our diet for increased energy and sense of well being.

Moringa does not like cold and loses it leaves in the winter. For climate where the winter is much, where it freezes and snows, it is recommended that moringa should be planted in pots, keeping them outside in the spring and summer and bring them inside when it gets cold. A greenhouse is ideal in most area. The plant will die if it freezes completely. Moringa loses it leaves when the average temperature drops below 70 degree.

Moringa grows in a variety of climates and substandard soil and it is as fast growing as it is hearty. Normal growth ranges from 3.5 meters per year if left uncropped. It is one of the fastest growing biomasses on the planet when nourished. The seed stock from moringa farms has varieties known to grow 7 meters in one year if left unchecked. A fully matured moringa tree can grow to 35 feet commercial moringa plantations usually crop the trees so they do not exceed 3-4 meters.The height allow the harvesters reasonable access and the cropping encourages horizontal growth enabling greater leaf production (Sreeja, 1985).

2.4.2 Cultivation of Moringa in Nursery

A poly bags with dimensions of about 18cm in height and 12cm in diameter is used. The soil mixture for the sacks should be light i.e 3 parts soil to 1 part sand. Plant two or three seeds in each science, one to two centimeters deep. The soil should be kept moist but not too wet. Germination will occur within 5 to 12 days, depending on the age of the seed and the pre-treatment method used. Remove extra seedlings, leave one in each sack. Seedlings can be out-planted; a hole should be made in the bottom of the sack big enough to allow the roots to emerge. The soil around the roots should be maintained (Fugile, 1999).

2.4.3 Planting Moringa in the Field

If planting a large plot it is recommended that the land should be ploughed first. Prior to plant a seed or seedling, a hole should be dug about 50cm in depth and the same in width. The planting hole serves as to loosen the soil and help to retain moisture in the root zone, enabling the seedlings root to develop rapidly. Compost or manure at the rate of 50kg per pit can be mixed with the fresh top soil around the pit and use to fill the pit.

The soil taken out of the pit should not be used for this purpose; fresh top soil contains beneficial microbes that can promote more effective root growth. The day before out planting water the filled pits or wait till a good rain before out-planting seedlings. The hole should be filled before transplanting the seedlings. In areas of heavy rainfall, the soil can be shaped in the form of a mound to encourage drainage.

The plant is not to be watered heavily for the first few days. If the seedlings fall over, they should be tied to stick about 40cm high for support. However, if water is available for irrigation, trees can be seeded directly and grown anytime during the year (Sreeja, 1987).

2.4.4 Effect of Pest and Diseases on Moringa Plant

Moringa is resistance to most pests. In a very water logged conditions, diplodia root can occur. In a very wet condition seedling, can also be planted in mounds so that excess water is drained off, cattle, sheep, pigs, and goat will eat moringa seedling, pod and leaves. The moringa tree should be protected from livestock by installing a fence or by planting a living fence around the plantation. A living fence can be grown with jetropha curcas, whose seed also be a problem, especially when cuttings are planted, which can be prevented by applying mulches of castor oil plant leaves, mahogany chips, tephrosia leaves or Persian lilac leaves around the base of the plant (Fugile, 1999).

2.5 Harvesting Moringa Seeds

When harvesting pods for human consumption, harvest when the pods are still young (about lcm in diameter) and snap easily (Sreeja, 1985). Older pods develop a tough exterior, but the white seed and flesh remain edible until the ripening process begins.

When the seed of moringa is to be used for planting or oil extraction, the pod is allowed to dry and turn brown on the tree. In some cases, it may be necessary to prop up a branch that holds many pods to prevent it breaking off. The pods should be harvested before they split open and seeds fall to the ground. Seeds can be stored in a well-ventilated sack in dry, shady places.

When harvesting moringa for making leaf sauces, harvest seedlings, growing tips or young leaves. Older leaves must be stripped from tough and wiry stems. These older leaf are more suited to making dried leaf powder since the stems are removed in the pounding and sifting process (Sreeja, 1987).

2.6 Processing and Preservation of Moringa Seed

Drumstick (moringa oleifera) pieces processed and preserved at coimbatore TNAU center by curing process (10% saline alone and in combination with 1% acetic acid) and by canning process (in 10% saline and tomato pulp from local and hybrid variety tomatoes) were found to be good without any fungal attack after one year of storage (Katayon, 2006).

2.7 Mechanical Properties

Information in engineering is the fundamental bedrock into innovation. As a matter of fact, it will undoubtedly enhance techno-scientific development with respect to food production.

To increase the economic importance of moringa seed production together with the complexity of modern technology for its mechanical production,its properties must be carefully studied and understood as they play important role in the design of machine structure, processes and control

Some of these properties that are useful in the processing of biological material include, size & shape.

Size and shape are inseparable in physical object and both are generally necessary if the object is to be described satisfactory.

Criteria for describing shape and size are found in the table 2.2.

Table 2.2 Description of the Shapes of Biomaterials

SHAPE	DESCRIPTION
Round	Approaching spheroid
Oblate	Flatten at stern and apex
Oblong	Vertical diameter long or than horizontal diameter
Comic	Egg-shaped and broad at stern
Elliptical	Approaching ellipsoid
Truncate	Having both end squared
Unequal	One half larger than other
Regular	Horizontal section approaches a circle
Irregular	Horizontal section depart materially from a circle

Source: (Mohsenin, 1970)

Some studies on the physical properties and mechanical properties of agricultural material are as follows;

The fracture resistance and cracking force of a palm-nut (local variety) were measured in terms of compressive force in the lab using universal testing machine the bulk of palm-nut was initially graded into three categories small size nut (S.S.N) medium size nut (M.S.N) and large size nut (L.S.N) with geometric mean diameter ranging between 11 to 30cm.

Factors that affect the magnitude of fracture force and cracking force include moisture content, weight, density, size, thickness of the shell, loading position (orientation) and so on. The effects of these factors were investigated. Three levels of moisture content used were 4%, 6% and 8% (wet basis) shell thickness varied from 1.5 - 6.0mm, fracture force varied from 0.1KN-1.7KN while cracking force varied from 0.2KN - 3.7KN. Knowledge of physical properties among others is a prerequisite for effective design of processing machinery of plant material.

The physical characteristics of direct influence on the design are of the plant material. The study of physical characteristics of castor nut shows that the dimensional properties which include the geometric shape, size parameters, size distribution, probability verses dimension, correlation between dimension and dimensional classification, capsule thickness and void were evaluated. The result thus obtained fully describe the physical characteristics of castor-nut grown in Nigeria (Mohsenin, 1970).

The development of processing procedure and requirement for biological material requires in depth knowledge and utilization of established characteristics of plant material. Traditional processing of castor-nut to cover the kernel is by pounding in a mortar and then shifted for further processing to recover oil. The process is slow and tedious.

The resistance characteristics of castor-nut was investigated to study the bio-yield point in a force deformation curve and the ability of the material to resist penetration through hardness test. These information on the mechanical properties are essential in the design of equipment and system for processing castor nut. Three varieties of castor nut at different moisture content were loaded in three principal positions on the hardness and the force needed to rapture the seed coat indicated a significant with increase in moisture content. The loading position and variety of the nut indicated the significant effect of the hardness value of the nut. Maximum hardness value is recorded, the average compressive force required to cause castor nut to rapture decreases from 4 to 6% (wet basis).

Ogunwurni (1998) studied some physical and engineering properties of cashew nut of relevant industrial application. These include shape, colour, size, weight, volume, sphericity, density, surface area, terminal velocity, force deformation, angle of repose and toughness value. The result shows that cashew nut has an average major diameter of 32.4mrnPrninor diameter of 20.0mm and the intermediate diameter of 25.9mm. It also has an average weight of 7.779, volume of $7.2 \times 10^{-6} m^3$, surface area of $6.0 \times 10^{-4} rn^2$, sphericity of 0.78, terminal velocity of 16.48rn/s, force of deformation 197.18N, deformation of 0.68rnm, angle of repose 27%, toughness value 26.42 joules and firmness value of 7.35NIrnm.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

The material used for this project in determining the physical and Mechanical properties of Moringa seed are:moringa seeds(from Rafi Local Gorvernment Area,Niger State),Kiya hardness tester,container,electric oven,electronic weighing balance and hand lens.

3.2 Methods

3.2.1 Shape of Material

To determine the shape of Moringa seed, the tracing of the longitudinal and lateral cross section of Moringa seeds was done. This is then compared with the shapes listed in a standard chart (Mohsenin, 1970), descriptive terms were used to define the shape of the product over five replicate.

3.2.2 Size of Material

To determine the size of Moringa seed according to (Mohsenin, 1970), the three principle diameter which is referred to as major, minor and intermediate diameter were measured using venier calliper and an average is taken over twenty replicates.

Where,

a = Major diameter, mm

c = Minor diameter, mm

b = intermediate diameter, mm

3.2.3 Weight of Material

The weight of Moring a seed was determined using digital weighing balance. Results were obtained for twenty replicates and the average was recorded.

3.2.4 Sphericity

This is a measure of how close is the material to a sphere. The sphericity of Moring a seed was determined by obtaining the values of the major, minor and intermediate diameter of the seed. The sphericity was calculated using the formular (Mohsehnin, 1970)

$$\text{Sphericity} = \frac{D_g}{a} \times 100$$

Where,

a= major diameter, mm

b= intermediate diameter, mm

c= Minor diameter, mm

$(a.b.c)^{1/3}$ = Geometric mean diameter, (mm)

3.2.5 Surface Area

Due to the unavailability of planimeter, and also the size of the Moringa seeds, the surface area was found by analogy with a sphere of the same geometric mean diameter, using the following relationship (Altuntaset and Demirtola, 2005).

$$S = \pi Dg^2$$

Where,

S = surface area, mm^2

Dg = Geometric mean diameter, mm

3.2.6 Geometric Mean Diameter

The geometric mean diameter of the material was determined from the major (a), minor (b) and intermediate (c) diameter using the formular;

$$\text{Geometric mean diameter (Dg)} = (a.b.c)^{1/3}$$

3.2.7 Moisture Content

The moisture content of Moringa seed was determined by oven dry method at 105^0C. The seeds were kept in the oven for eight hours and it was reweighed at every two hours interval until there is no more reduction in weight. The moisture content was then calculated using the formular (Mohsenin, 1970).

$$\text{Moisture content (m.c)}_{db} = (W_2 - W_3)/(W_3 - W_1) \times 100$$

Where,

W_1= Weight of container, g

W_2= Weight of wet sample + container, g

W_3= Weight of dry sample + container, g

3.2.8 Volume

The volume of Moringa seed was determined by using the following formular

$$\text{Volume (v)} = \frac{\pi B L^2}{6(2L - B)}, \text{mm}^3$$

Where;

$B = (WT)^{1/2}$

L= Major diameter, mm

W= Minor diameter, mm

T= Intermediate diameter, mm

3.2.9 Density

The density was determine by ratio of weight to the volume (Mohsenin, 1970)

$$\text{Density } (\rho) = \frac{\text{Weight (g)}}{\text{Volume (cm}^3)}, \text{g/cm}^3$$

3.2.10 Static Coefficient of Friction

The static coefficient of friction (μ) was determined with respect to three different surfaces plywood, glass and galvanized iron. A hollow metal cube, open at both ends was filled with the seed and placed on adjustable tilting surface, such that the metal cube did not touch the surface. Then the surface was raised gradually until the filled cube just start to slide down, the angle at this point was recorded and the static coefficient of friction was calculated using the following formula

$$\mu = \tan \theta.$$

3.3 Selected Mechanical Properties

The mechanical properties are those having to do with the behavior of a material under applied forces while rheological properties are those having to do with deformation and flow due to the action of forces. The machine used in determining some mechanical properties of moringa seed is "KIYA HardnessTester"Kiya Seisakusho Ltd,Tokyo,Japan,which was used for determining hardness, rupture, crack and breakage of some biomaterials, the equipment ranges from 0kg- 20kg.

3.3.1 Test Procedure

The hardness test was carried out following the America society of Agricultural Engineers Standard (ASAE, 1986). The material (moringa seed) was placed on a platform provided on the machine. The calibration is set to zero and the spindle of the machine was turned by applying manual effort continuously until the spindle becomes stiff to turn and the load at this point was recorded as the hardness, continuous gradual turning of the spindle and observing the material with the aid of hand lens to determine the load at rupture, crack and breakage over five replicates and the average was taken and recorded.

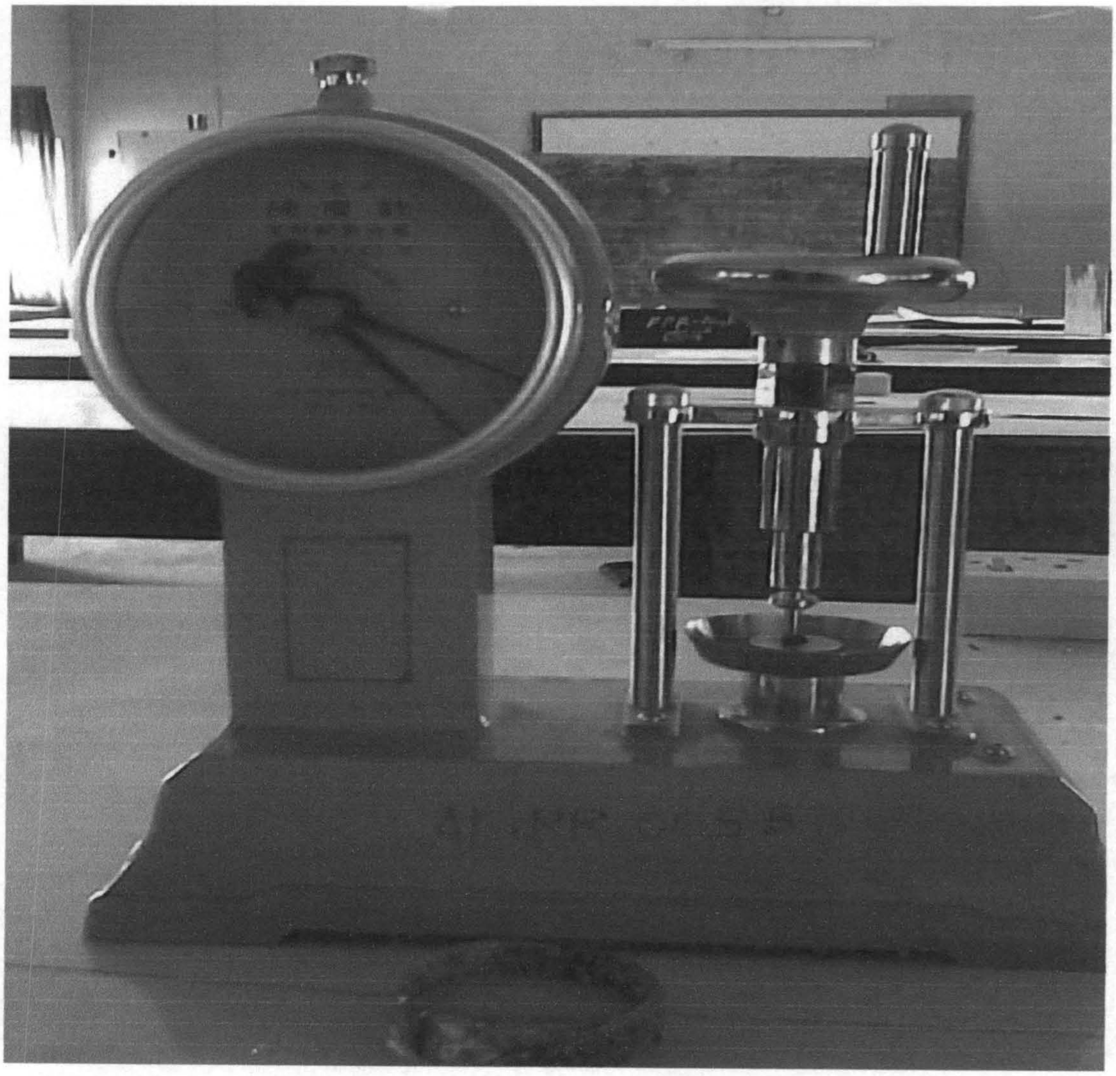

Plate 3.1 Kiya Hardness Tester

Plate 3.2. Showing the experimental test

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation of Results

The determined physical and mechanical properties of moringa seed are presented in Table 4.1

Table 4.1 Results of the determined physical and mechanical properties of moringa seed.

Properties	No of samples	Maximum	Minimum	Mean	SD	CV
Shape	5		approaching spheroid			-
Major dia, (mm)	20	9.8	7.00	8.38	0.70	0.08
Minor dia, (mm)	20	8.30	5.60	7.06	0.83	0.12
Intermediate dia, (mm)	20	7.76	4.20	5.66	0.82	0.15
Weight, (g)	20	0.33	0.13	0.25	0.06	0.15
Geometric mean dia, (mm)	20	8.11	5.51	6.92	0.62	0.09
Surface area, (mm^2)	20	206.3	95.38	151.86	26.33	0.17
Volume, (mm^3)	20	32.74	13.79	22.57	4.40	0.20
Density, (g/cm^3)	20	12.90	9.10	10.96	1.48	0.14
Static coefficient of friction						

Glass	3	0,21	0.19	0.20	0.001	0,005
Plywood	3	0.34	0.32	0.33	0.001	0.003
Galvanized sheet	3	0.42	0.39	0.40	0.013	0.00
Moisture content, (%)	50	-	-	5.86	-	-
Hardness, (N)	5	27.0	25.0	26.0	0.63	0.02
Rupture, (N)	5	42.0	35.0	38.2	2.56	0.07
Cracking force, (N)	5	56.0	52.0	53.2	2.93	0.06
Breakage force, (N)	5	80.0	62.0	68.0	7.04	0.10
Shpericity, (%)	20	100.14	75.13	82.85	6.67	0.08

* SD = Standard Deviation ** CV = Coefficient of Variation

4.2 Discussion of Results

A summary of the results of the determined physical and mechanical properties of moringa Oleifera seed parameter at moisture content of 5.86% dry basis is shown in table 4.1. The average major minor and intermediate diameters were found to be 8.38mm, 7.06 and 5.66mm respectively, while their standard deviation and coefficient of variation were 0.70, 0.83, 0.82 and 0.08, 0.12 and 0.15 respectively. These parameters are important in determining sieve sizes in dry cleaning operation because the smaller the value of coefficient of variation the better is the separation. The geometric mean diameter is 6.92mm while the corresponding surface Area is 151.86mm^2, while their corresponding (SD) and

(CV) were 0.62, 26.33 and 0.09 and 0.17 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 behaviors in a flowing fluid such as air, as well as ease of separating extraneous materials from the particle during cleaning by pneumatic means. The sphericity was 82.85% while the (SD) and (CV) were 6.67 and 0.08 respectively. This is an indication of a tendency toward the shape of a sphere. The average weight, volume and density were 0.25g, 22.57mm^3 and 10.96g/cm^3, while their corresponding (SD) and (CV) were 0.06, 4.40, 1.48 and 0.15, 0.20 and 0.14 respectively. This shows that moringa seeds were heavier than water. This characteristic can be used to design a separation or cleaning process for grains since lighter fractions will float. The average values of static coefficient of friction against galvanized iron sheet, plywood and glass sheet were 0.40, 0.33, and 0.20, while their (SD) and (CV) values were 0.013, 0.001, 0.001 and 0.00, 0.003 and 0.005 respectively. These parameter are used in determining the angle at which chute or drum washer must be positioned in order to achieve consistent flow of material through them during conveyance or washing respectively. The mean values of hardness, rupture force, crack and breakage forces were 26N, 38.2N,53.2N and 68N, while their (SD) and (CV) were 0.63, 2.56, 2.93, 7.04 and 0.01. 0.07, 0.06 and 0.10 respectively. These parameters are also important in the design of machines for processing biomaterials particularly in the design of a press for extracting oil from oil producing seeds. These parameters gives the energy requirement and consideration governing equipment selection in size reduction operations.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The following conclusions were drawn from the determined physical and mechanical properties of moringa seed at moisture content of 5.86%. The average major, minor, intermediate and geometric mean diameter were 8.38mm, 7.06mm, 5.66mm and 6.92mm respectively. The average weight, volume, density and surface area were 0.25g, 22.57mm^3, 10.96g/cm^3 and 151.86mm^2 respectively. The average static coefficient of friction on glass, plywood, galvanized sheet and sphericity were 0.20, 0.33, 0.40 and 82.85% respectively. The hardness, rupture force, cracking force and breakage force were determined to be 26N, 38.2N, 53.2N and 68N respectively. These data generated can be used in designing equipment and machines for harvesting, handling and processing moringa seed.

5.2 Recommendations

1. Other properties of moringa seed should be worked on to provide fairly comprehensive information in design parameters.

2. 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.

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APPENDICES

APPENDIX

VALUES OF THE PHYSICAL PROPERTIES OF MORINGA SEED AT MOISTURE CONTENT OF 5.86%

S/N	a	c	b	W	D_g	S	Φ	V	ρ
				X					
	(mm)	(mm)	(mm)	(g)	(mm)	(mm^2)	(%)	(mm^3)	(g/cm^3
1	8.64	7.80	6.00	0.30	7.40	172.03	85.64	25.61	11.71
2	8.60	8.00	7.76	0.31	8.11	206.63	94.30	32.74	9.47
3	8.24	5.60	5.30	0.19	6.25	122.72	75.85	17.52	10.85
4	9.50	7.40	6.20	0.30	7.58	180.51	79.79	26.16	11.46
5	8.00	7.76	5.00	0.21	6.77	143.99	84.63	21.37	9.83
6	8.70	8.30	5.20	0.31	7.21	163.31	82.87	24.04	12.90
7	8.94	6.98	5.30	0.28	6.92	150.44	77.41	22.46	12.47
8	7.94	6.00	4.64	0.16	6.05	114.99	76.20	16.43	9.74
9	7.00	7.24	6.80	0.25	7.01	154.38	100.14	25.75	9.71
10	8.34	8.00	6.30	0.33	7.49	176.24	89.81	26.99	12.23
11	8.64	7.46	5.60	0.33	7.12	159.26	82.41	23.35	14.13
12	7.54	6.48	5.60	0.19	6.49	132.32	86.07	19.79	9.60
13	8.34	7.70	6.60	0.23	7.51	177.19	90.05	27.19	8.46
14	8.00	6.70	6.00	0.20	6.85	149.41	85.63	21.99	9.10
15	9.80	7.40	6.00	0.30	7.58	180.51	77.35	25.88	11.59
16	9.00	7.00	5.30	0.26	6.94	151.31	77.11	21.69	11.99
17	7.00	5.70	4.20	0.13	5.51	95.38	78.71	13.79	9.43
18	9.00	6.00	5.74	0.26	6.77	143.99	75.22	20.55	12.65
19	8.34	7.84	5.00	0.25	6.89	149.14	82.16	21.88	11.43
20	8.00	5.90	4.60	0.17	6.01	113.48	75.13	16.18	10.51

AVERAGE VALUES OF THE PHYSICAL PROPERTIES OF MORINGA SEED AT 5.86% MOISTURE CONTENT

a	c	b	W	D_g	S	Φ	V	ρ
				$\overline{X}$				
(mm)	(mm)	(mm)	(g)	(mm)	(mm^2)	(%)	(mm^3)	(g/cm^3)
8.38	7.06	5.66	0.25	6.92	151.86	82.85	22.57	10.96

VALUES OF THE MECHANICAL PROPERTIES AT 5.86% MOISTURE CONTENT

S/N	Hardness	Rupture force	Crack	Breakage force
		X		
	(N)	(N)	(N)	(N)
1	26.0	35.0	55.0	62.0
2	27.0	36.0	48.0	64.0
3	26.0	42.0	52.0	62.0
4	26.0	40.0	56.0	72.0
5	25.0	38.0	55.0	80.0

AVERAGE VALUES OF THE MECHANICAL PROPERTIES AT 5.86% MOISTURE CONTENT

Hardness	Rupture force	Crack	Breakage force
	$\overline{X}$		
(N)	(N)	(N)	(N)
26.0	38.2	53.2	68.0

VALUES OF THE STATIC COEFFICIENT OF FRICTION OF MORINGA SEED

S/N	Glass	Galvanize Iron	Plywood
1	0.19	0.32	0.40
2	0.21	0.34	0.39
3	0.19	0.34	0.42

AVERAGE VALUES OF STATIC COEFFICIENT OF FRICTION OF MORINGA SEED

	Glass	Galvanize Iron $\overline{X}$	Plywood
	0.20	0.33	0.40

SQUARED DEVIATION OF PHYSICAL PROPERTIES OF MORINGA SEED

S/N	a	c	b	W	D_g	S	Φ	V	ρ
				$(X - \overline{X})^2$					
	(mm)	(mm)	(mm)	(g)	(mm)	(mm^2)	(%)	(mm^3)	(g/cm^3
1	0.07	0.55	0.12	0.03	0.32	406.83	7.78	9.24	0.56
2	0.05	0.88	4.41	0.004	1.42	2999.75	131.10	103.43	2.22
3	0.02	2.13	0.13	0.004	0.45	849.14	49.0	25.50	0.01
4	1.25	0.12	0.29	0.003	0.44	820.82	9.36	12.89	0.25
5	0.14	0.49	0.44	0.002	0.02	69.94	3.17	1.44	1.28
6	0.10	1.54	0.21	0.004	0.08	131.10	0.00	2.16	3.76
7	0.31	0.01	0.01	0.001	0.00	2.02	29.59	0.01	2.28
8	0.19	1.12	1.04	0.08	0.76	1359.40	44.22	37.70	1.49
9	1.90	0.03	1.30	0.00	0.01	6.35	298.94	10.11	1.56
10	0.00	0.88	0.41	0.006	0.33	594.38	48.44	19.54	1.16
11	0.07	0.16	0.00	0.006	0.04	54.76	0.19	0.61	10.05
12	0.71	0.34	0.00	0.004	0.19	381.81	10.36	7.73	1.85

13	0.00	0.41	0.88	0.00	0.35	641.61	51.84	21.34	6.25
14	0.14	0.13	0.12	0.003	0.01	6.00	7.75	0.34	3.46
15	2.02	0.12	0.12	0.003	0.44	820.82	30.25	10.96	0.40
16	0.38	0.00	0.13	0.00	0.00	0.30	32.95	0.77	1.06
17	1.90	1.85	2.13	0.014	1.99	3189.99	17.14	77.09	2.34
18	0.38	1.12	0.01	0.00	0.02	61.94	58.22	4.08	2.86
19	0.00	0.61	0.44	0.00	0.00	7.40	0.06	0.48	0.22
20	0.14	1.35	1.12	0.006	0.83	1473.02	59.60	40.83	0.20

MEAN SQUARED DEVIATION OF PHYSICAL PROPERTIES OF MORINGA SEED

a	c	b	W	D_g	S	Φ	V	ρ
				$\Sigma(X - \bar{X})^2/N$				
(mm)	(mm)	(mm)	(g)	(mm)	(mm^2)	(%)	(mm^3)	(g/cm^3)
9.77	13.84	13.43	0.07	7.61	13869.38	889.95	386.25	43.8

SQUARED DEVIATION VALUES OF MECHANICAL PROPERTIES OF MORINGA SEED

S/N	Hardness	Rupture force	Crack	Breakage force
		$(X - \bar{X})^2$		
	(N)	(N)	(N)	(N)
1	0.00	10.24	3.24	36.0
2	1.0	4.84	27.04	16.0
3	0.00	14.44	1.44	36.0
4	0.00	3:24	7.84	16.0
5	1.0	0.04	3.24	144.0

MEAN SQUARED DEVIATION OF MECHANICAL PROPERTIES OF MORINGA SEED

S/N	Hardness	Rupture force	Crack	Breakage force
		$(X - \bar{X})^2/N$		
	(N)	(N)	(N)	(N)
	2.0	32.8	42.8	248.0

STANDARD DEVIATION OF THE PHYSICAL AND MECHANICAL PROPERTIES OF MORINGA SEED (SD)

SD for Major Diameter $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{9.77 \cdot \frac{1}{20}} = 0.70$

SD minor diameter $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{13.84 \cdot \frac{1}{20}} = 0.83$

SD for intermediate diameter $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{13.43 \cdot \frac{1}{20}} = 0.82$

SD for weight $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{0.07 \cdot \frac{1}{20}} = 0.06$

SD for D_g $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{7.61 \cdot \frac{1}{20}} = 0.62$

SD for surface area $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{13869.38 \cdot \frac{1}{20}} = 26.33$

SD for sphericity $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{889.95 \cdot \frac{1}{20}} = 6.67$

SD for volume $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{386.25 \cdot \frac{1}{20}} = 4.40$

SD for density $= \sqrt{\Sigma(x-\bar{x})2 \cdot {}^1/_n} = \sqrt{43.8 \cdot \frac{1}{20}} = 1.48$

$$\text{SD for hardness} = \sqrt{\Sigma(x-\bar{x})2 \cdot {}^{1}/_{n}} = \sqrt{2.0 \cdot \tfrac{1}{5}} = 0.63$$

$$\text{SD for rupture} = \sqrt{\Sigma(x-\bar{x})2 \cdot {}^{1}/_{n}} = \sqrt{32.8 \cdot \tfrac{1}{5}} = 2.56$$

$$\text{SD for crack} = \sqrt{\Sigma(x-\bar{x})2 \cdot {}^{1}/_{n}} = \sqrt{42.8 \cdot \tfrac{1}{5}} = 2.93$$

$$\text{SD for breakage} = \sqrt{\Sigma(x-\bar{x})2 \cdot {}^{1}/_{n}} = \sqrt{248 \cdot \tfrac{1}{5}} = 7.04$$

$$\text{SD for glass} = \sqrt{\Sigma(x-\bar{x})2 \cdot {}^{1}/_{n}} = \sqrt{0.0003 \cdot \tfrac{1}{3}} = 0.01$$

$$\text{SD for galvanized sheet} = \sqrt{\Sigma(x-\bar{x})2 \cdot {}^{1}/_{n}} = \sqrt{0.0003 \cdot \tfrac{1}{3}} = 0.01$$

$$\text{SD for plywood} = \sqrt{\Sigma(x-\bar{x})2 \cdot {}^{1}/_{n}} = \sqrt{0.0005 \cdot \tfrac{1}{3}} = 0.013$$

COEFFICIENT OF VARIATION OF PHYSICAL AND MECHANICAL PROPERTIES OF MORINGA SEED (CV)

$$\text{CV for major diameter} = \frac{SD}{\bar{x}} = \frac{0.70}{8.38} = 0.08$$

$$\text{CV for minor diameter} = \frac{SD}{\bar{x}} = \frac{0.83}{7.06} = 0.12$$

$$\text{CV for intermediate diameter} = \frac{SD}{\bar{x}} = \frac{0.82}{5.66} = 0.15$$

$$\text{CV for weight} = \frac{SD}{\bar{x}} = \frac{0.06}{0.25} = 0.24$$

$$\text{CV for geometric mean diameter} = \frac{SD}{\bar{x}} = \frac{0.62}{6.92} = 0.09$$

$$\text{CV for surface area} = \frac{SD}{\bar{x}} = \frac{26.33}{151.86} = 0.17$$

$$\text{CV for volume} = \frac{SD}{\bar{x}} = \frac{4.40}{22.57} = 0.20$$

$$\text{CV for density} = \frac{SD}{\bar{x}} = \frac{1.48}{10.96} = 0.14$$

$$\text{CV for glass} = \frac{SD}{\bar{x}} = \frac{0.001}{0.20} = 0.005$$

$$\text{CV for plywood} = \frac{SD}{\bar{x}} = \frac{0.001}{0.33} = 0.003$$

$$\text{CV for galvanize sheet} = \frac{SD}{\bar{x}} = \frac{0.013}{0.40} = 0.00$$

$$\text{CV for hardness} = \frac{SD}{\bar{x}} = \frac{0.63}{26} = 0.02$$

$$\text{CV for rupture} = \frac{SD}{\bar{x}} = \frac{2.56}{38.2} = 0.07$$

$$\text{CV for cracking} = \frac{SD}{\bar{x}} = \frac{2.93}{53.2} = 0.06$$

$$\text{CV for breakage} = \frac{SD}{\bar{x}} = \frac{7.04}{68} = 0.10$$

$$\text{CV for sphericity} = \frac{SD}{\bar{x}} = \frac{6.67}{82.85} = 0.08$$

MOISTURE CONTENT (Dry Basis) OF MORING SEED

Weight of empty container $W_1 = 26.151g$

Weight of wet sample + container $W_2 = 38.07g$

Weight of dried sample + container $W_3 = 37.41$

$$\text{Moisture Content} = \frac{W2 - W3}{W3 - W1} = \frac{38.07 - 37.41}{37.41 - 26.15} = 5.86\%$$