DETERMINATION OF RHEOLOGICAL PROPERTIES OF JATROPHA (SEED)

BY

OJOMAH, AUGUSTINE

MATRIC N0. 2005/21581EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING,

FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

JANUARY, 2011

DETERMINATION OF RHEOLOGICAL PROPERTIES OF JATROPHA (SEED)

BY

OJOMAH, AUGUSTINE

MATRIC N0. 2005/21581EA

DEPARTMENT OF AGRICULTURAL AND BIORESOURCES ENGINEERING, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA

JANUARY, 2011

DETERMINATION OF RHEOLOGICAL PROPERTIES OF JATROPHA (SEED)

BY

OJOMAH, AUGUSTINE

MATRIC N0. 2005/21581EA

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

JANUARY, 2011

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 and diploma or certificate at any university or institution. Information derived from personal communications, internet, published and unpublished work were duly referenced in the text.

21-02-2011

Ojomah, Augustine

Date

CERTIFICATION

This is to certify that the project entitled "Determination of Rheological Properties of *Jatropha Cuscas* Seed" by Ojomah, Augustine 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.

Dr. D. Adgidzi
Supervisor

21.02.2011
Date

Engr. Dr. A. A. Balami
Head of Department

21-02-2011
Date

External Examiner

13/01/2011
Date

Dedication

This project work is dedicated to the Almighty God, who, in his infinite mercies, saw me through the moments of disappointment and moments of joy throughout this period.

I praise His holy name for all his benefits and goodness toward me. He alone is worthy to be praise.

Acknowledgements

Energy and resources have gone into the completion of this project work. There were times of disappointment, times of sorrow and times of joy. There were also periods I thought that I know it all and also period I know nothing. I give glories to Almighty God, for sparing my life in good health and making it possible to successfully complete this project work. I wish to express my profound gratitude to my project supervisor, Engr. Dr. D. Adgidzi for his patience , assistance and concern towards this project work wishes him the very best in all his endeavors in life.

I want to use this privilege to thank my able and dynamic lecturers of the noble and interesting department of Agricultural and Bioresources Engineering of the Federal University of Technology, Minna for their patience with me in times when I had offended them and for the warm hands of parenthood which the extend to me at time I needed their support most.

I want to thank Mrs O.M. Oluwafemi, Miss Ronke Owolabi and all the member of the staff of Engineering Materials Development centre. Akure in Ondo State who assisted me greatly by providing for me an environment to carryout the test. I also want to specially thank Mrs. Heline Joseph Odigure for her financial assistance throughout my studies, I say may God who know how to reward, will reward you and give you good health, prosperity and long life to enjoy the fruit of your labour. My profound gratitude goes to my dear parent, Mr and Mrs Inelo Ojomah for their affectionate inspirations which have sparred me to this level of academic attainment. I pray that God will give you good health, prosperity and long life to enjoy the fruit of your labor. I want to thank the lady of my dreams miss Gloria Odoma for her love and care throughout this period of my life. I also thank those who have contributed in one way or the other toward the success of this project work.

Abstract

Rheological properties of agricultural materials are important in predicting the behavior of the materials to damage during mechanized harvesting, handling and processing. In this study, some rheological properties of jatropha curcas seeds were determined experimentally under the mass range of shelled 0.51 - 0.58 and unshelled 0.80 - 0.87 and the parameter determined were moisture content, seed weight, rupture point and modulus of deformability and the result obtained from the one having moisture content values 11.01 % produced rupture point of 179.86 N for 35.07 mm while the one with moisture content values 13.60 % also produced rupture point of 607.48 N for 42.74 mm and corresponding deformation indicate that the properties measured are affected by moisture content.

TABLE OF CONTENTS

List of Tables pages

List of figures

CHAPTER ONE

1.0 INTRODUCTION

Jatropha curcas (euphorbiacée called pinion of India) is a specie originating in the Indies and currently widespread in the villages of tropical Africa (Adjanohounet al., 1989). In Congo, this plant is found in almost all the areas. The population uses it in the textile industry and its many therapeutic virtues (Kerharo, 1974). Jatropha curcas is a drought resistant tropical tree and the oil from its seeds has been found useful for medicinal and veterinary purposes, as insecticide, for soap production and as a fuel substitute (Gubitz et al., 1999).There is a large variability in different accessions of Jatropha curcas from diverse agro climatic regions (Kaushik et al., 2007). Augustus et al. (2002) have reported that Jatropha curcas seeds contain around 20 – 40 % oil. Its soil fraction consists of both saturated (14.1 % palmitic acid and 6.7 % stearic acid) and report (Martinez-Herrera et al., 2006) that the major fatty acids found in the oil samples were oleic (41.5 - 48.8 %), linoleic (34.6 - 44.4 %), palmitic (10.5 - 13.0 %), and stearic (2.3 - 2.8 %)acids. Because of the strong competition between human consumption and the soap factory for the use of vegetable oils, it is advantageous that Africa develops other sources of vegetable oils of production. The curcas of Jatropha is instigator, because the seed contains oil 58 % roughly (Kerharo, 1974). Jatropha curcas is an oil plant. It is significant to point out that, the non-edible vegetable oil of Jatropha curcas has the requisite potential of providing a promising and commercially viable alternative to diesel oil since it has desirable physico-chemical and performance characteristics comparable to diesel. Cars could be run with Jatropha curcas oils without requiring much change in design.

s

1.1 Few advantages of jatropha curcas are given below:

>> Jatropha is adapted to a wide range of climates and soils.

>> It can grow almost on any type of soil whether gravelly, sandy or saline and thrives even on the poorest stony soils and rock crevices.

>> It is a drought resistant perennial living up to 50 years.

The tree grows up to a height of 3 meters, which means harvesting is an easy task. A hybrid variety of jatropha could give three harvests in a year, compared to two harvests by other varieties of jatropha. It takes two years for a 'Jatropha' sapling to begin producing seeds, and they can produce seeds for up to 30 years. The seeds are crushed to extract raw oils, Jatropha seeds contain about 35 % of non-edible oil. Furthermore, vegetable oil-based products hold great potential for stimulating rural economic development because farmers would benefit from increased demand for vegetable oils. Various vegetable oils, including palm oil, soybean oil, sunflower oil, rapeseed oil, and canola oil have been used to produce biodiesel fuel and lubricants (Demirbas, 2003) Biodiesel is mono-alkyl esters of fatty acids derived from vegetable oils or animal fats, is known as a clean and renewable fuel. Biodiesel is usually produced by the transesterification of vegetable oils or animal fats with methanol or ethanol (Knothe et al., 2006). Biodiesel has many advantages include the following: its renewable, safe for use in all conventional diesel engines, offers the same performance and engine durability as petroleum diesel fuel, non-flammable and nontoxic, reduces tailpipe emissions, visible smoke and noxious fumes and odors. The use of biodiesel has grown dramatically during the last few years. Feedstock costs account for a large percent of the direct biodiesel production costs including capital cost and return (Bozbas, 2005). One way of reducing the biodiesel production costs is to use the less expensive feedstock containing fatty acids such as inedible oils, animal fats, waste food oil and by products of the refining vegetables oils (Veljkovic′ et al., 2006). The availability and sustainability of sufficient supplies of less expensive feedstock will be a crucial determinant delivering a competitive biodiesel to the commercial filling stations. Fortunately, inedible vegetable oils, mostly produced by seed-bearing trees and shrubs can provide an alternative. With no competing food uses, this characteristic turns attention to Jatropha curcas, which grows in tropical and subtropical climates across the developing world (Open shaw, 2000). The fact that Jatropha oil can not be used for nutritional purposes without detoxification makes its use as energy or fuel source very attractive as biodiesel. In Madagascar, Cape Verde and Benin, Jatropha oil was used as mineral diesel substitute during the Second World War (Agarwal, 2007). Jatropha curcas is a multipurpose bush/small tree belonging to the family of Euphorbiaceae. It is a plant with many attributes, multiple uses and considerable potential. The plant can be used to prevent and/or control erosion, to reclaim land, grown as a live fence, especially to contain or exclude farm animals and be planted as a commercial crop. It is a native of tropical America, but now thrives in many parts of the tropics and sub-tropics in Africa/Asia (Gubitz et a., 1999; Kumar and Sharma, 2008; Open Shaw, 2000; Martınez-Herrera et al., 2006). The wood and fruit of Jatropha can be used for numerous purposes including fuel. The seeds of Jatropha contain viscous oil, which can be used for manufacture of candles and soap, in cosmetics industry, as a diesel/paraffin substitute or extender. This latter use has important implications for meeting the demand for rural energy services and also exploring practical substitutes for fossil fuels to counter green- house gas (GHG) accumulation in the atmosphere. These characteristics along with its versatility make it of vital importance to developing countries (Kumar and Sharma, 2008).

1.2 **Background to the Study**

According to the environmental worries and the consumption of non-renewable natural energy resources, developing alternative resources of energy as a substitute of traditional fossil fuels has risen. Biodiesel is among those alternatives and it is defined as an alternative fuel for diesel engines produced by Chemically reacting a vegetable oil or animal fat with an alcohol such as methanol or mono-alkyl esters of long chain fatty acids derived from a renewable lipid feed stock, such as vegetable oil or animal fat (Ma and Hanna, 1999; Van Gerpen, 2005; Wang et al., 2006). Vegetable oils were proposed as diesel fuels as they are widely available from a variety of sources and they are renewable (Boehman, 2005; Wan Nik et al., 2005). On the other hand, they were found to be problematic due to their greater viscosity which is affecting piston, injector deposits and oil thickening (Baldwin et al., 1982; Fuls et al., 1984; Peterson et al., 1983; Ryan etal., 1984; Van Der Wat and Hugo, 1982). Conversion of the oils to their alkyl esters reduced the viscosity to near the diesel fuel levels and produced a fuel with properties that were similar to petroleum based diesel fuel and which could be used in existing engines without modifications. The main advantages of using biodiesel fuels as

100 % methyl or ethyl esters of vegetable oil and animal fat or biodiesel blends (up to 20 % blend to the diesel fuel) are producing less smoke and particulates, having higher cetane numbers and producing lower carbon monoxide and hydrocarbon emissions (Antolin et al., 2002; Encinar et al., 2007).They also present some technical challenges such as low volatility, high pour and cloud points and cold filter plugging temperature. They contain essentially no sulfur; therefore, greatly reduce sulfur dioxide emissions from diesel vehicles (Alptekin and Canakci, 2008; Saifuddin and Chua, 2004; Vicente et al., 2004). As an alternative to diesel fuel, biodiesel must be technically feasible, economically competitive, environmentally acceptable and readily available. Nowadays, biodiesel fuel is used in public traffic for performing farm engines, lighting and heating of rooms in specific conditions (Haas, 2005; Schlautman et al., 1986; Tomasevic and Siler Marinkove, 2003). However, biodiesel cost is higher than the oil derived diesel due to the cost of virgin vegetable oil. Therefore, it is necessary to explore ways to reduce production cost G. El Diwani, et al.220 of biodiesel. Minimizing the cost of raw materials is a special interest. There are a number of non-edible tree based oil seeds available (Kayasiri et al., 1996; Phan and Phan, 2008) in many countries around the world. Jatropha is one of such non-edible oils cultivated in southern Egypt and irrigated with primary treated municipal wastewater. Using this non-edible oil for making biodiesel has a great opportunity of making it economically feasible (Tiwari et al., 2007). In addition, it helps in reducing the cost of advancing wastewater treatment

1.3 Statement of the problem

Currently due to gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions, there is an urgent need to develop alternative energy resources, such as biodiesel fuel, which is oil extracted from Jatropha seed is one of the important biodiesel fuel and that is why it is necessary to know the viscosity and flow rate of the oil gotten from the seed in order to use the biodiesel effectively and efficiently.

1.4 Objectives of the Study include

To determine the rheological properties of jatropha seed (shelled and unshelled) such as

i. Bioyield point, rupture point and force and deformation under applied load.

ii. Modulus of deformability

1.5 Justification of the Study

Jatropha seed has the advantage that not only is it capable of growing on marginal land, but it can also help to reclaim problematic lands and restore eroded areas. As it is not a food or forage crop, it plays an important role in deterring cattle, and thereby protects other valuable food or cash crops. Jatropha seeds can be pressed into bio-oil that can be used to run diesel engines, which in turn can drive pumps, food processing machinery, or electricity generators. The bio-oil can also be the basis for soap making. The pressed residue of the seeds is a good fertilizer and Vegetable oil is a promising alternative because it has several advantages, it is renewable, environ-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy.

Therefore, in recent years several research have been studied to use vegetable oils as fuel in engines as biodiesel.

1.6 Scope of the Study

The scope of this research work is only restricted to the determination of rheological properties of Jatropha seeds (both shelled and unshelled).

CHAPTER TWO

2.0 LITERATURE REVIEW

Jatropha is a genus of approximately 175 succulent plants, shrubs and tree some are deciduous, like jatropha seed (shelled and unshelled) from the family Euphorbiaceae. The name is derived from (Greek iatros = physician and trophe= nutrition), hence the common name physic nut. Jatropha is native to Central America and has become naturalized in many tropical and subtropical areas, including India, Africa, and North America. Originating in the Caribbean, Jatropha was spread as a valuable hedge plant to Africa and Asia by Portuguese traders. The mature small trees bear separate male and female flowers, and do not grow very tall. As with many members of the family Euphorbiaceae. Jatropha contains compounds that are highly toxic. The hardy Jatropha is resistance to drought and pests, and produces seeds containing 27 – 40 % oil (average: 34.4 %). The remaining press cake of jatropha seeds after oil extraction could also be considered for energy production. Goldman Sachs recently cited Jatropha curcas as one of the best candidates for future biodiesel production however the concept about jatropha oil dated back to 1885 when Dr. Rudolf Diesel, built the first diesel engine with the full intention of running the engine on vegetable oil. He first displayed his engine at the pairs show in 1900 and surprised every one when he ran the patented engine on the hydrocarbon fuel available, which include gasoline and peanut oil. A rheometer as described by Nzikou et al., (2007) was used to measure the different oil viscosities. By this procedure, a concentric cylinder system is submerged in the oil and the force necessary to overcome the resistance of the viscosity to the rotation is measured. The viscosity value, in m Pas, is automatically calculated on the basis of the speed and the geometry of the probe. Temperature (20 ^{0}C) was controlled with a water bath connected to the rheometer. The experiment was carried out by putting 3 ml of sample in a concentric cylinder system using 100 G1 as shear rate. Chemical analysis: Determinations for peroxide, iodine, saponification values, un-saponifiable matter and free fatty acid contents were carried out using Pena et al., (1992) standard analytical methods. The fatty acid composition was determined by conversion of oil to fatty acid methyl esters prepared by adding 950 of n-hexane 50 mg of oil followed by 50:1 of sodium meth oxide using the method of Cocks et al.,(1996). The mixtures were vortex for 5 sand allowed to settle for 5 min. the top layer (1:1) was injected into a gas chromatograph (Model GC - 14A, Shimadzu Corporation, Kyoto, Japan) equipped with a flame-ionization detector and a polar capillary column (BPX70 0.25), 0.32 mm internal diameter, 60 m length and 0.25 m film thickness (SGE Incorporated, USA) to obtain individual peaks of fatty acid methyl esters. The detector temperature was 240 ^{0}C and column temperature was 110 ^{0}C held for one minute and increased at the rate of 8 ^{0}C min G1 to 220 ^{0}C and held for one minute. The run time was 32 min. the fatty acid methyl esters peaks were identified in comparing their retention time with those of standards. Percent relative fatty acid was calculated based on the peak area of a fatty acid spices to the total peak area of all the fatty acids in the oil sample. The minerals were determined by atomic absorption spectrophotometer. One gram samples, in triplicate, were dry ashed in a muffle furnace at 550 ^{0}C for 8H until a white residue of constant weight was obtained. In 1912, he then stated the used of vegetable oil for engine fuel may seem insignificant today but such oils may in course of time become as important as petroleum and the coal tar products of present time. The viscosity of the plant pure oil (PPO) is more or less constant for a given kind of oil, but may incresase with aging of the PPO. The viscosity at room temperature is much higher than for rapeseed (see above tables). It has an enormous influence on the atomization of the fuel upon injection, possibly causing incomplete combustion with excess noise, smell and emissions and (in the longer run) engine damage. Some kinds of injection equipment may take permanent damage from running with too high fuel viscosity.

2.1 **Particles (contamination)**

Particles of too large size can have an abrasive effect on the injectors and the combustion chamber walls and can plug filters etc. A plugged filter is annoying, but not dangerous. The filter is a safety measure preventing contamination of the fuel system. First pressing trials of unfiltered Jatropha oil contains much more sediment than rapeseed oil (about 30 % against 5 %). Removal of sediment by filtering or by centrifugation is of immanent importance. A good mesh size of the filter cloth is 5 micron.

2.2 Water

Water is naturally present in the oil in small amounts. Its amount should be kept as low as possible, because it can cause cavitation, erosion and corrosion in the injection system. Furthermore a boundary between water and oil in the tank (possible above some 0.1 %) may provoke the development of bacteria and fungi that block Scientist (Martinez-Herrera et al., 1970) also discovered that the viscosity (thickness) of vegetable oil could be reduced by a simple chemical process and can work as well as diesel fuel in model engine. Since the technical development, have largely been completed, plant oil is highly valued as biofuel and transformed into biodiesel in most

plate 2.1 Physical description of Jatropha plant (Heller, 1996)

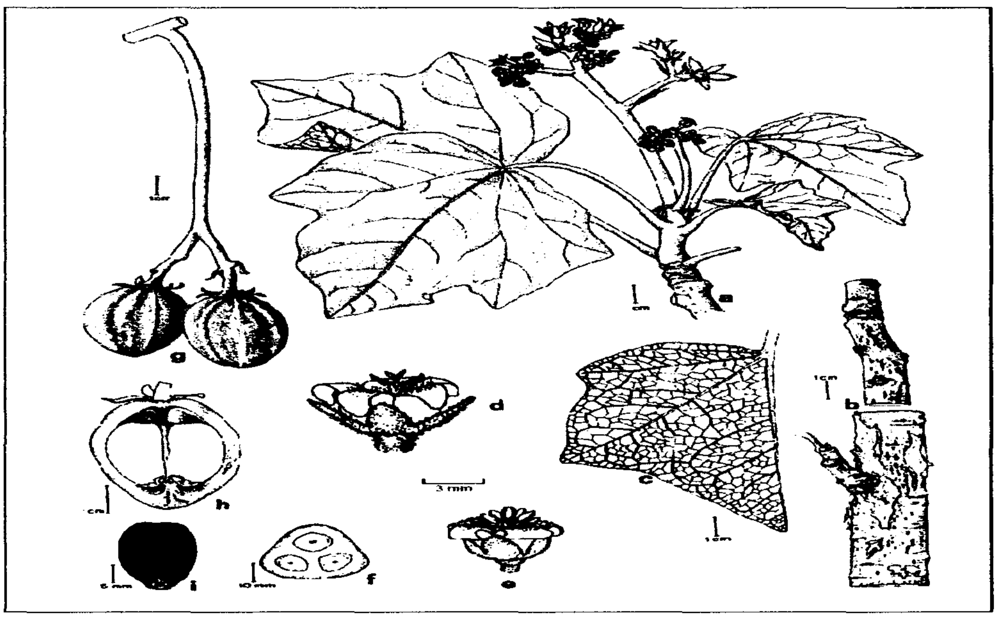

plate 2.2 Left: representation of the Jatropha plant (a,b,c,d) fruits(g,h) and seeds (i)

Right : close up of Jatropha fruits near Arusha, Tanzania (Heller, 1996).

It is a tall bush or small tree (up to 6 m height). The lifespan of this perennial bush is more than 50 years, and it can grow on marginal soils with low nutrient content. Jatropha Curcas, or "physic nut" has a straight trunk with thick branch lets. It has green leaves with a length and width of 6 to 15 cm. the fruit have an "American Football" type of shape, of about 40mm length and each contains 3 seeds (on average), which look like black beans, with similar dimensions, of about 18 mm long (11 - 30) and 10mm wide (7 - 11) the seed weight per 1000 seeds is about 750 grams, which is equivalent of 1333seeds per kg on average. The seeds contain more than 30 % of oil by weight (Tz 38 %, of which some 30 s% can be gained using cold pressing). The branches contain whitish latex, which causes brown stains that are difficult to remove. Normally five roots are formed from seeds: one tap root and 4 lateral roots. Plants from cuttings do not develop the tap root, only the laterals. The appearance of the plants in a hedge can vary a lot. You may find plants with no leaves (dormant position) beside plants with green leaves. Both the availability of water and sunlight have influence on this effect. Akintayo (1997) reported a 47.25 % yield by weight of the seed. Variations in oil yield may be due to the differences in variety of plant, cultivation climate, ripening stage, the harvesting time of the seeds and the extraction method used (Che Man et al.,1995). Starting with farm layout and a land conservation program, a farm plan is created for the site including irrigation, power, out buildings, field layout, and complete evaluation of all renewable resources the property offers for the development of green energy. We also work directly with land owners and farm managers throughout the process adapting your system to the specific needs for the ocation of jatropha farm. We assist by providing management, equipment, and training that have been proven on our farm and to co-op members worldwide. As a traditional co-op, we also provide marketing tools for our members. This includes our Jatropha Conference and Expo which held every May, starting in 2009. At the conference, we will offer Jatropha Fuel Futures to the United State and International Bio-diesel producers for next year's upcoming crop. This allows the cooperative to provide funding for farming contracts to its members that propagate and harvest Jatropha. Currently FBI-Farms managers and is actively farming over 10,000 m acres in the United States, 12,000 acres in Mexico, 25,000 acres in Colombia, 25,000 in Costa Rica, totaling over 70,000 acres of Jatropha plantations working together, sharing information, and technology. Everything we have developed or implemented on your farm is passed on to the co-op members. Jatropha curcas (euphorbiacee called pinion of India) is a spices originating in the Indies and currently widespread in the villages of tropical African (Adjanohoun et al., 1989). In Congo, this plant is found in almost all the areas. The population uses it for the clothes industry of the fences and in the pharmacopeia, in reason of its many therapeutic virtues (Kerharo, 1974).

Jatropha curcas, is a drought resistant tropical tree and the oil from its seeds has been found useful for medicinal and veterinary purposes, as insecticide, for soap production and as a fuel substitute (Gubitz et al., 1999). There is a large variability in different accessions of Jatropha curcas from diverse agro climate regions (Kaushik et al., 2007, Augustus et al., 2002) have reported that Jatropha curcas seeds contain around 20 – 40 % oil. Its oil fraction consists of both saturated (14.1 % palmitic acid and 6.7 % strearic acid) and unsaturated fatty acids (47 % oleic and 31.6 of linoleic acid). Recently, there is a report (Martinez-Herrera et al., 2006) reported that the major fatty acids found in the oil samples were oleic (41.5 - 48.8 %),linoleic (34.6 - 44.4 %), palmite (10.5 - 13.0 %), and stearic (2.3 - 2.8 %) acids. Because of the strong competition between human consumption and the soap factory for industrialized nation of the World. We are in energy crises and our enemies are threatening us with oil, therefore, our huge investment into Bio-fuel is reality and bio-fuel is a substitute to fast depleting fossil fuel and has come to stay (Barrack Oboma U.S president) Nigeria is endowed with Jatropha plants and has the best variety world over. Bio-diesel would reduce the price and conversed our non renewable energy with bio-fuel so our future energy is secure (Engr Mustafa Bello former minister of commerce). Heating profiles of Jatropha curcas oil extracted by two methods (Blye and Dyer and Soxlhet), at 2.5^{0}C minG1 scan rate Fig.2 : Heating profiles Jatropha Curcas oil extracted by Blye and Dyer method at 2.5^{0}and 5^{0}C.minG1 scan rate by Akintayo (2004) and Kpoviessi et al.,(2004). The extracted oils were liquid at room temperature. The oil content of Jatropha characteristic of the oil were compared with Jatropha curcas varieties others country, described curcas "Congo-Brazzaville" seed sand the level at which the differences are significant are shown in Table 3. The oil extraction with Soxlhet method had the highest yield, due to the increased ability of the solvent to overcome forces that bind lipids within the sample matrix (Lumley et al., 1991). The Blye and Dyer method, showed the low yield of the oil to losses during the separation of the two phases, aqueous layer (methanol-water) and organic layer (chloroform). The results of the above authors agree with those of the present work, despite its abundance and use as an oil and reclamation plant, none of the Jatropha species have been properly domesticated and, as a result, its productivity is variable, and the long-term impact of its large-scale use on soil quality and the environment is known. With some modification it is possible to run many diesel engined vehicles on unrefined vegetable oil. The oil needs to be pre-heated, and well filtered before use to prevent coagulation.

Biodiesel is the name given to any diesel equivalent biofuel which can be used in an unmodified diesel engine vehicle. General biodiesel is most commonly made with a mixture of vegetable oil and methanol. With a flash point of 160 degrees C it is classified as non-flammable, and it is also bio-degradable and non-toxic. On its own biodiesel have much lower emissions than petrodiesel, and it can also be mixed with petroldiesel to reduce emissions. B20 for example is a fuel containing 20 % biodiesel and 80 % petrodiesel. Pure biodiesel is B100. Biodiesel reduces carbon dioxide emission by 78 % and carbon monoxide emission by 50 %. It also completely eliminates sulphur emissions. For vehicles made before the early 1990's there is a problem with the use of biodiesel. The rubber hoses and gaskets used before that time can de-grade in the presence of biodiesel. Newer cars have synthetic hoses and gaskets, and of course older cars can have their hoses and gaskets replaced before bio-diesel is introduced. Biodiesel is also more solvent than pertoldiesel and so it will rapidly break down any despite of old residue in a vehicle's fuel lines and fuel tank and clog the fuel filter. Therefore, after making the transition to biodiesel it is important to change the fuel filter around 1000 miles after switching. "Jatropha" is usually used to refer to the species Jatropha Curcas, although there are approximately 170 known species of the plant. This is grown in hectare between 350 - 500 saplings, and seed production range between 1.5 – 1.2 tons per hectare or the yield per hectare is up to 5 tons seed given about 1.85 tons of oil in the year (El- Gamassy, 2008). Jatropha Curcas a member of the Euphorbiaceae family is a multipurpose tree of significant economic importance because of its several industrial and medicinal uses (Makkar et al., 2008). Jatropha bush and have multiple uses it well to produce outstanding biodiesel as fuel and due to fires without emissions that pollute the environment, so-called oil friend of the environments is also used for lighting and several other industrial purposes (El-Gamassy, 2008). Jatropha grow throughout most of the tropics. It survives on poor stony soils and can be used to reclaim land (Munch and Kiefer, 1989). Jatropha curcase plants start yielding from the second year of planting, but in limited quantity. If managed properly, it starts giving 4 -5 kg of 94 Afr. J. Food Sci. seed per tree production from the fifth year onwards and seed yield can be obtained up tom 40 - 50 years from the day of planting (Kumar et al., 2003). The seed Jatropha is at present still a wild plant it is not cultivated through variety research. It belongs to the Euphorbia family. The plant and its seeds are non edible (toxic) to animals and humans and are therefore used worldwide as hedges (living fences) to protect agricultural fields.

2.3.0 **Agronomy**

2.3.1**Germination of the seeds**

With good moisture conditions the germination of the seed takes 10 days The seed shell splits and the radicula emerges and four peripheral roots are formed (Soon after the development of the first leaves, the cotyledons wither and fall off.

2.3.2 **Flowering**

Flowering can commence even during the first year in 5 month after sowing, but this is only under extremely favorable conditions. Normally, flowering follows a longer period of vegetative development. Fruit development takes 90 days, from flowering until seed maturation. In regions with a dry and a wet season, flower formation seems to be induced by the onset of the rainy season. It may flower again after having produced fruits, this second round of flowering may lead to another yield if conditions remain favorable for another 90 days. When conditions remain favorable after two generative cycles Jatropha does not respond by another round of flowering but grows vegatively.

Reproduction will stop as soon as the dry season begins. In permanently humid regions flowering occurs during the whole year.

2.3.3 Development

Development corresponds to the rainy seasons: vegetative growth occurs during the rainy season, there is little increment or even leaf fall during the dry season.

Plants can gain a height up to 5 m. and reach more than 50 years of age.

There are various methods of propagation of Jatropha, either generative orvegetative. Each

2.3.4 Propagation methods

method has a different labor intensity and risk for good establishment. The following plates are the physical description of Jatropha curcas plant

Plate 2.3 Unshelled Jatropha seed and are therefore used worldwide as hedges (living fences) to protect agricultural fields. (Heller, 1996)

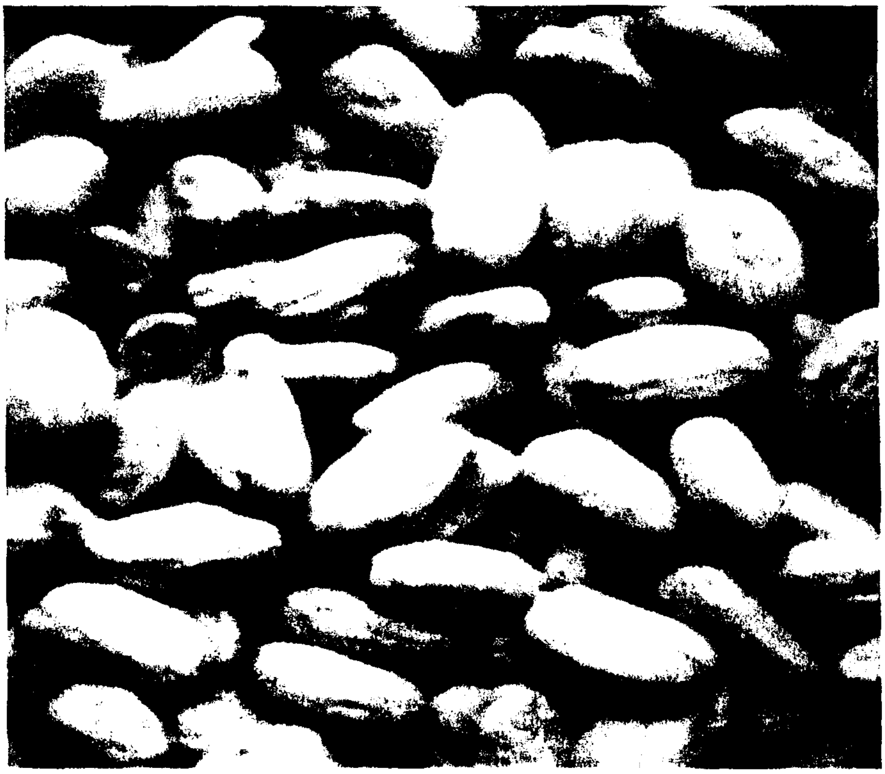

plate 2.4 Shelled Jatropha seed and are therefore used worldwide as hedges (living fences) to protect agricultural fields. (Heller, 1996)

The term "Jatropha" is usually used to refer to the species Jatropha Curcas, although there are approximately 170 known species of the plant. Jatropha is at present still a wild plant- it is not cultivated through variety research. It belongs to the Euphorbia family. The plant and its seeds are non edible (toxic) to animals and man fences) to protect agricultural fields.

2.6 Properties

Many investigations have been done on the content of the Jatropha seeds. The seed oil is 80 percent unsaturated, made up mainly of oleic and linoleic acid. Most vegetable oils that are liqui om temperature have a comparable fatty acid composition.

2.7.0 **Toxicology**

The toxicity of the seeds is mainly due to the presence of "curcin" and "diterpine", "curcin" is similar to "ricin", the same toxic protein as present in castorbean (Ricinus communis), "diterpine esters" (we call them phorbol esters) which have been isolated from seeds and roots. Since the seed cake still contains oil, it also contains the toxic diterpenes, and so can not be used for fodder. Until now, no mutagenic properties have been proved for the oil, and thus there is no danger for workers.

2.7.1 **Use of the whole Plant:**

2.7.2 **Erosion control as hedge plant**

In the tropics, the plant is widely used as s hedge in fields and settlements. It protects plants against wind erosion and keeps animals out (Yasmin et al., 2008; Magdi, 2007; Ramakrishna et al., 2006; Aderibigbe et al., 1997). The Jatropha is chosen for this purpose mainly because it can easily be propagated by cuttings, densely planted for this purpose, and because the species is not browsed by cattle. The root also form a protection against water erosion, and can protect against soil erosion by runoff if planted with Vetiver grass or lemon grass. When grown from seeds, the plants are edible ffor the first 3months, since the toxic material has not been developed yet. It should be protected from animals in these early stages. It can also be eaten safely, when steamed or stewed. Jatropha hedges are commonly used in Cape Verde, also for fighting soil erosion, Mail, Upper Guinea, Burkina Faso, Zimbabwe, and also in El Salvador.

plate 2.5 Dense Jatropha hedges in Tanzania (Photo Ruud van Eck, Diligent 1996

2.7.3 **Medicinal use**

The name "Jatropha" refers to medicinal uses, from the Greek jatros, meaning "doctor" and "trophe", meaning "food". Preparations of all parts of the plant, including seeds, leaves and bark, fresh or as a decoction, are used in traditional medicine and veterinary purposes. The oil has a strong purgative action and is widely used to treat skin diseases and to soothe pain from rheumatism. The sap flowing from the stem is used to control the bleeding of wounds.

2.7.4 **Plant protecting Viruses**

Unfortunately Michael Allen (2002) says that the physical nut is a host for viruses that attack also cassava, since they belong to the same family of plants (such as the cassava super elongation disease). Therefore physic nut should not be used to fence in cassava fields. For some countries it should be investigated if it does not contain viruses for major crops. One issue raised in Mozambique, for example, was that it could possibly contain viruses harmful to cashew nut trees, which occur in large quantities all over the country.

2.7.5 **Firewood and green manure**

The plants and fruit hulls could be used for firewood, but it is a low quality wood. The leaves and the fruit hulls can be used as green manure in the field.

2.7.**6 Seed oil uses**

The seed oil can be used for production of soap, directly as fuel in oil lamps or stoves, or as pure plant oil (PPO) for diesel engines.

2.7.7 **Soap Production**

In former times Portugal imported Jatropha seeds from the Cape Verde islands to produce soap. From the 20's to the 60s some 2000 tons of seeds were imported per year on average. Presently soap is produced by artisanal methods in Mali and Tanzania (Arusha) and for short in Zimbabwe. The oil is boiled with a soda solution (Henning, 1994) and poured into moulds, in which it hardens out into soap during cooling of. The soap has positive effects on the skin and is therefore marketed for medicinal purposes. The local production of soap is one of the most economically attractive uses of Jatropha oil.

plate 2.6 Left: Pongamia seeds, middle Jatropha seeds, righttop: soap from Kakute Tanz, below, Oil from Diligent (Heller, 1996)

2.7.8 **Sources 0f Fuel**

After pressing the seeds, the filtered oil can be directly used as PPO in diesel engines. Because slightly different properties of pure plant oil (PPO) compared with fossil oil and it was discovered that the diesel gotting from jatropha seed has a low carbon monoxide which is harmful to man and even to plant, this types of diesel engines must be adapted. Generally the Diesel engine is very suited to run on PPO. In fact Rudolf Diesel (1954) designed his first engine to run on plant oil as well. Many types of diesel engines have indirect injection (IDI) with pre-chambers. The PPO can be used freely in these engines, which are still commonplace in developing countries. Some typical brand names are: Lister, Deutz, IFA, DMS, and Farymann. Probably most of these are IDI types. Elsbett diesel engines have been designed especially for the use of PPO. Direct Injection diesels can also run on PPO, but some modifications have to be made to the engines. Mainly cold start and low-load situation (idling etc.) are dangerous when using pure plant oil PPO. A two-tank system, using PPO only for full load of the hot engine, overcomes most problems. The engine should be monitored properly for lubrication oil production or consumption and coke deposit in the combustion chamber. To produce a generally usable biofuel for any diesel engine, the PPO can be converted to biodiesel with a trans-esterification process. The resulting biodiesel can be used in any diesel engine without adaptations (except for pure rubber hoses which detoriate after longer contact with pure biodiesel). This is not a complex process, but requires the addition of methanol (or ethanol) and caustic soda, increasing the cost of the final product. This is mostly done in Europe, notably in Germany and France, from rape seed oil. This process, requires the use of electricity, and therefore bio-diesel production is typically feasible on a large scale, at centralized production plants. It is not so suitable for small scale applications, although small systems have been designed in india, powered by human pedaling force (cycling).

2.7.9 **Seed cake use as manure**

A good application for the seed cake is to use it as organic manure, replacing chemical fertilizer. It has nitrogen content similar to that from cake of castor bean or chicken manure. The nitrogen content ranges from 3.2 to 3.8 % (Juiliet et al 1955; Moreira 1979; Vohringer 1987). The GTZ project in Mali (1995) carried out a fertilizer trial with pearl millet where the effects of manure (5 t/ha), physic nut press cake (5 t/ha) and mineral fertilizer (100 kg ammonium phosphate and 50 kg urea/ha) on pearl millet were compared. Pearl millet yields per ha were: 630 kg for control, 815 kg for manure, 1366 for press cake and 1135 kg for mineral fertilizer. As the costs for mineral fertilizer were higher than those of the press cake, the rent ability was US$ 60, higher for the latter (Henning et al, 1995). The press cake is appreciated by the farmers and can be sold for 10 FCFA per kg (US$ 0.02/kg).

2.7.10 **Input for biogas production**

The seed cake still contains oil. Hence the seed cake still contains much energy. The cakein principle be converted into bio-gas by digestion in bio-gas tanks, together with other input materials, such as dung, leaves etc. The biogas can be used for cooking and lighting. The residue can still be used as organic fertilizer, as it retains all of its minerals and nutrients. The use of seed cake as a single digestion input has been researched by Foidl et al. (1997) and Diligent/TUE (2005) but requires further investigation.

2.7.11 **Input for combustion production**

Seed cake can be processed into pellets using screw-type presses. These pellets can be used for direct combustion, or they can be converted into charcoal where there is sufficient demand for charcoal, such as in the neighborhood of large cities where there is a deforestation problem, such as in Tanzania. No experiments are known so far Work is done on this topic by Diligent and others.

Biodiesel produced by trans-esterification reaction can be catalyzed with alkali, acid or enzyme. Chemical catalyst processes, including alkali and acid ones are more practical compared with the enzymatic method. Alkali process can achieve high purity and yield of biodiesel product in a short time (Dorado et al., 2004; Meher et al., 2006a; Tiwari et al., 2007). Methyl or ethyl ester are the product of transestrification of vegetable oils with alcohol (methanol/ ethanol) using an alkaline catalyst. In addition, the process yields glycerol which has great applications in the pharmaceutical, food and plastics industries

(Bouaid et al., 2005; Meher et al., 2006b; Sirvastava and Prasa, 2000). The purpose of this work is to study the rheological properties and compared it's bioyield point, rupture point while loading the seed (both unshelled and shelled Jatropha seed) and selects the best process at pilot plant scale using jatropha oil as the raw material with methanol and sodium hydroxide as the catalyst and evaluate the produced biodiesel as a fuel. This study has been carried out in National Research Centre in Egypt during winter 2007. Viscosity defined as resistance liquid to flow. Viscosity increased with molecular weight but decreased with increasing unsaturated level and

Temperature (Nouredini et al1992). At room temperature kinematic viscosity of the sample were detected at 42.88^0C the viscosity of jatropha oil must be reduced for biodiesel application since the kinematic viscosity of biodiesel were very low compare d to vegetable oil. High the jatropha oil seed are not suitable if its use directly as engine fuel, often results in operational problems such as carbon deposits, oil ring sticking, and thickening and gelling of lubricating oil as a result of contamination by the vegetable oils. Different methods such as preheating, blending, ultrasonically assisted methanol transesterification and supercritical methanol transesterification are being used to reduce the viscosity and make the m suitable for engine applications(pramanik,2003;Banapurmath 2008) the density of a material is defined as the measured of it mass of it per unit volume. The density of vegetable oil lower than that of water and the differences between vegetables oil are quite small, particularly among the common vegetable oils. Generally, the density of oil decreases with molecular weight, yet increase with unsaturation level (Gunstone, 2004)

In the oil industry, different processes must be done before oil extraction occurs, when Jatropha curcas fruits arrive different processes conducted before are:(a) dehulling, separating hull from nut, (b) deshelling, separating shelled from kernel, (c) drying.

Engineering (rheological) properties of seed are needed for the designing of equipment to handle transport, process, store and assessing the product quality and the aim of this studying this was to investigate the properties of Jatropha curcas seeds, and to be able to predict behavior of materials during mechanized harvesting, handling and processing. The part of optimization of shelling and oil extraction of Jatropha curcas for direct use in plant oil stoves. The considered parameters were dimension force-deformation at rupture point, at bioyield point, at differents, moisture content, are useful in designing of handling and processing equipment for agricultural materials.

CHAPTER THREE

METHODOLOGY

3.0 MATERIALS AND METHODS

The experiment was carried out with a universal testing machine at laboratory of the Engineering Material Development Institute (EMDI) Akure, Ondo State.

3.1 Materials and Sample selection

For this project work, dried Jatropha curcas seeds were gotten from the National Research for Chemical Technology, NARICT, Zaria. The seeds gotten were about 90 in number and 45 seeds were carefully shelled using a stone to crack the nut. Out of the 45 shelled seeds, 35 whole seeds were selected and also 35 whole unshelled seeds were also selected. The seeds were cleaned to remove any foreign matter or dirt in them.

Table 3.1 Parameters and materials used

Parameters	Materials used
Moisture content	Townsen and Mercer Oven drier
Seed weight	Digital laboratory weighing balance
Rupture point and	50 kN automated universal testing machine
Modulus of deformability	(Instron 4000 series,bluehill)

3.2.0 Method used

3.2.1 Moisture content determination

Oven dry method was used to carry out moisture content determination at the CropProcessing Laboratory, Agricultural and Bioresources Engineering department. Both shelled and unshelled Jatropha seeds were put in separate containers and their weights were taken using a digital weighing balance before both shelled and unshelled seeds were put in the oven drier at a temperature of 105^0c for 24 hours.

After 24 hours, the seeds were brought out of the oven and the weights of the seeds after oven drying was taken. Moisture content in (% d.b) was calculated using the formula below:

$$\text{Moisture content (\% d.b)} = \frac{\text{Weight of water removed}}{\text{Weight of dry sample}} \times 100$$

Table 3.2: Statistical analysis and Tabular representation of the Moisture content

Weight	Values
W, weight of can (g)	
W_1, weight of can + sample before oven drying (g)	
W_2, weight of can + sample after oven drying (g)	
Weight of water removed= $W_2 - W_1$	
Weight of dry sample= W_2 -Weight of can (g)	
Moisture content (% d.b)	

3.3 Sample classification

The shelled samples consisted of three Jatropha seeds and they were weighed; the mass range of the shelled seeds were from (0.51 - 0.58 g). the first, second and third shelled seeds weighed 0.51, 0.54 and 0.58 g respectively. while the unshelled seeds had a mass range from (s0.80 - 0.870 g). The first, second and third unshelled seeds weighed 0.804, 0.852 and 0.870 g.

3.4 Rheological Properties determination

Laboratory compression test were carried out using a compression tester (Instron-4000 series, place) and data was acquired and processed by a Bluehill software at the Mechanical testing laboratory, Engineering Materials Development Institute, Akure. Shelled and unshelled seeds were taken one after the other and placed in the machine under the flat steel compression tool, ensuring that the centre of the tool was in alignment with the peak of the curvature of the shelled and unshelled seeds. The test speed was set at 25mm per minute (Mohsenin, 1984) and the shelled and unshelled seeds were individually loaded to the point of rupture. A force-deformation curve and the Modulus were produced on the computer connected to the universal testing machine. The rupture point i.e. the rupture force and the corresponding deformation were got from the point on the curve where the material ruptured.

Table 3.3: Statistical analysis and tabular representation of some Rheological properties at Yield (zero slope) for shelled or unshelled seeds

S/N	Compressive extension at yield point (mm)	Compressive load at yield point (N)	Energy at yield point (J)	Compressive stress at yield point (MPa)	Compressive strain at yield point (mm/mm)
Min					
Max					
Mean					
St.dev					

Table 3.4: Statistical analysis and Tabular representation of some Rheological properties at rupture (break) point of shelled or unshelled seeds

S/N	Compressive extension. at rupture (mm)	Compressive load at rupture (N)	Compressive strain at break (mm/mm)	Compressive stress at break (MPa)	Energy at break (J)	Modulus of deformability (MPa)
Min						
Max						
Mean						
Stdev						

Table 3.5 Statistical analysis and tabular representation of Rupture point and Modulus of deformation of shelled and unshelled seeds.

No. of observations	Rupture point (N), (mm)	Modulus of deformability (MPa)
Min		
Max		
Mean		
St.dev.		

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 PRESENTATION OF RESULTS

Table 4.1: Rupture and Modulus of Deformability of shelled Jatropha curcas seeds

No. of observations	Rupture point N,	(mm)	Modulus of deformability (MPa)
1	179.85	(35.07)	2.50
2	162.79	(32.31)	3.72
3	157.47	(29.99)	7.30
Min	157.47	(29.99)	2.50
Max	179.85	(35.07)	7.30
Mean	166.71	(32.46)	4.51
St.dev.	11.69	(2.54)	2.49

Table 4.2: Rupture point and Modulus of deformability of unshelled Jatropha curcas seeds

No. of observations	Rupture point N,	(mm)	Modulus of deformability (MPa)
1	607.48	(42.74)	10.38
2	174.39	(34.96)	7.88
3	109.96	(32.67)	8.75
Min	109.96	(32.67)	7.88
Max	607.48	(42.74)	10.38
Mean	297.27	(36.79)	9.00
St.dev.	270.57168	(5.28)	1.27

4.2 DISCUSSION OF RESULTS

The moisture content in (% d.b) for the shelled Jatropha seeds were calculated to be 8.50 % d.b and the unshelled seeds was 13.60 % d.b

4.2.1 Interpretation of the Force-Deformation curves of shelled Jatropha curcas seeds

The force-deformation curve of the first shelled sample is shown in fig 4.1 below; the initial curve bends curves towards the compressive extension (deformation) axes indicating that there is relatively large deformation in response to initial small loading.

The compressive extension and compressive load at yield (zero slope) are 10.23 mm and 36.52N, while the compressive extension and load at rupture (break) are 34.86mm and 53.10N. The rupture point i.e. the rupture force and the corresponding deformation are 179.85N and 35.07mm. The modulus automatically produced by the software is 2.50MPa.

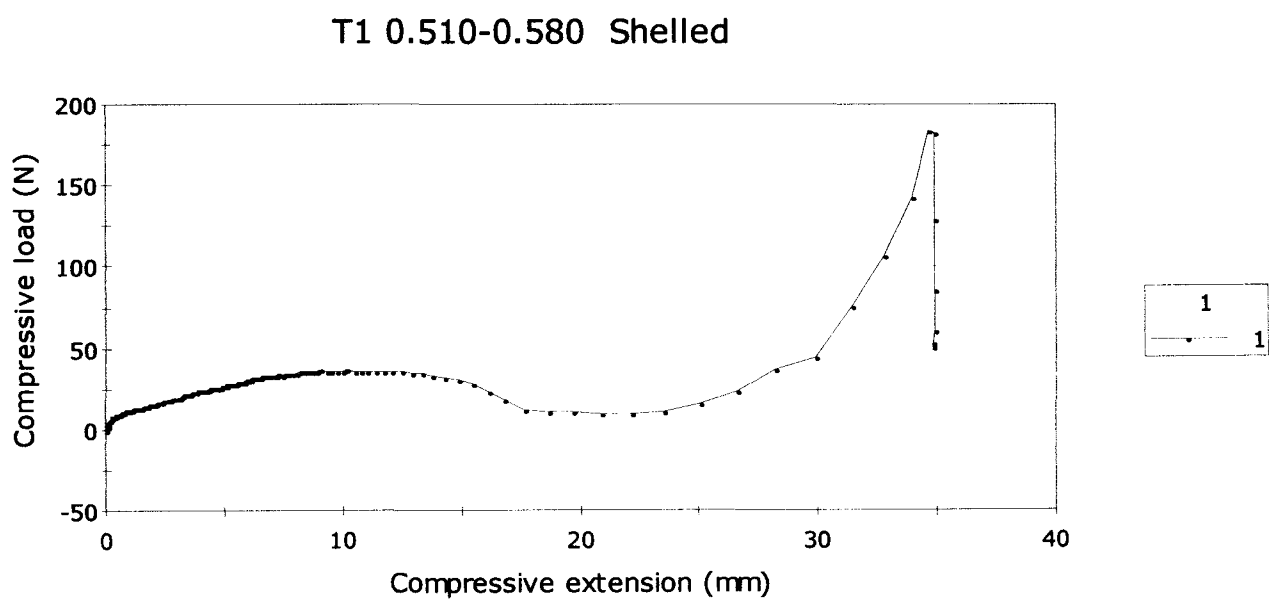

Fig. 4.1: Force-deformation curve of the first shelled Jatropha curcas seed.

The Force-deformation curve of the second shelled sample is shown in fig.4.2 below; The initial curve points towards the deformation (compressive extension), (mm) indicating a relatively large deformation in response to initial small loading, the second curve towards the compressive load axes signifies that deformation decreases as load increases and the third curve being linear indicates the point of rupture. The compressive extension and load at yield were 9.40 mm and 35.07 N, the compressive extension and load at rupture (break) were 31.72 mm and 54.68 N while the rupture point i.e. the rupture force and the corresponding deformation from the graph are 162.80 N and 32.31 mm respectively. The modulus automatically produced is 3.72 MPa.

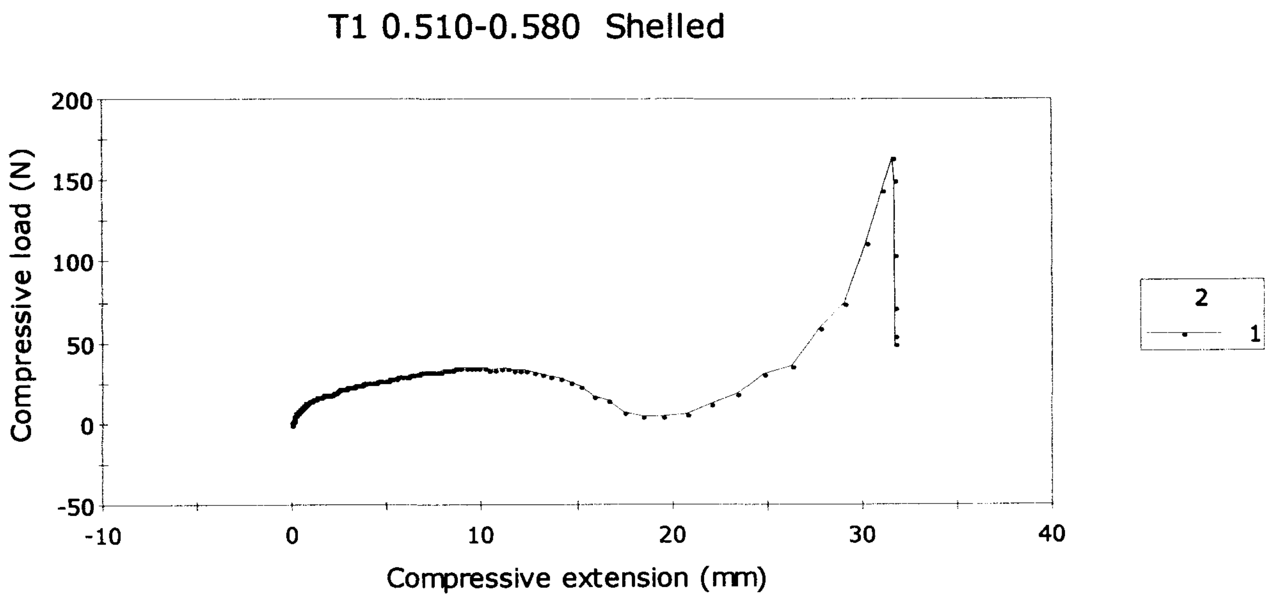

Fig.4.2: Force-deformation curve of the second shelled seed

The force-deformation curve of the third shelled sample is shown in fig.4.3 below; the curve is similar to that of fig.4.1 and 4.2. The compressive extension and load at yield point were 3.87 mm and 27.07 N, the compressive extension and load at rupture (break) were 29.86mm and 75.47 N. The rupture point i.e. the rupture force and the corresponding deformation from the graph (linear curve) were 157.47 N and 29.99 mm. The modulus automatically produced is 7.30 MPa.

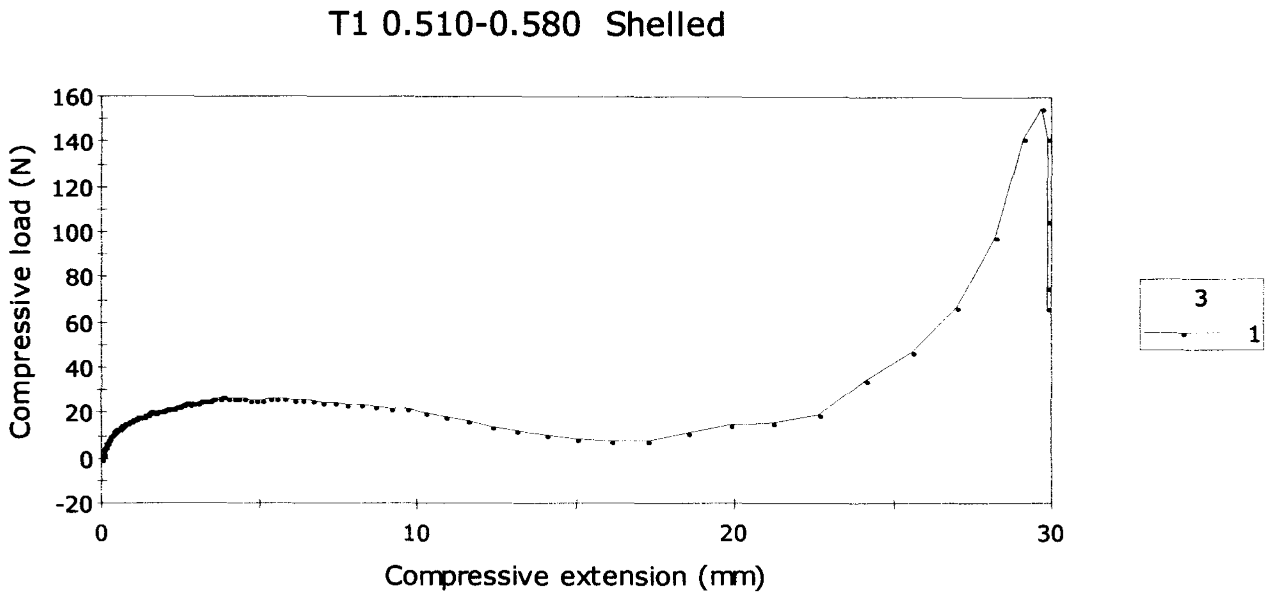

Fig.4.3: Force-deformation curve of the third shelled seed

4.2.2 Interpretation of the Force-deformation curve of unshelled Jatropha curcas seeds

The force deformation curve of the first unshelled seed is shown in the Fig.4.4 below; the initial curve is steep and short meaning that the shell of the nut ruptures under small load and deformation. The compressive extension and load at yield (zero slope) were 5.37 mm and 123.24 N, The compressive extension and load at rupture (break) were 42.50 mm and

398.28 N. The rupture point i.e. the rupture force and the corresponding deformation were 607.48N and 42.74mm respectively. The modulus automatically produced by the software is 10.38 MPa.

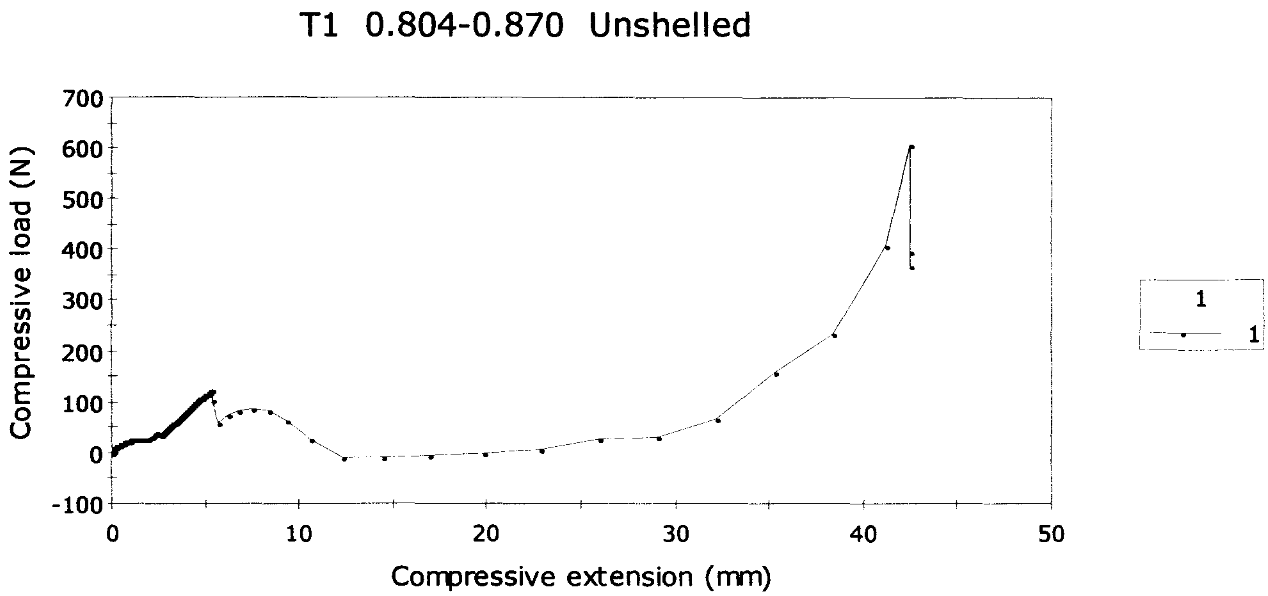

Fig. 4.4: Force-deformation curve of the first unshelled seed

The Force-Deformation curve of the second unshelled sample is shown in fig. 4.5 below; The initial curve from point zero is a steep curve which is shorter than that of fig. 4.4 and this indicates that the force required to rupture the shell is smaller when compared to that of fig.4.4. The shell of the nut ruptures after the small force exerted (immediately after the steep curve) and also loading of the kernel takes place before it yields at 126.28N and final ruptures at 174.39 N, (34.96mm). The compressive extension and load at yield (zero slope) are 2.21mm and 26.11N respectively. The compressive extension and load at rupture (break) are 35.23mm and 66.48N, the rupture point i.e. the rupture force and the corresponding deformation are 174.39N and 34.96mm. The modulus automatically produced by software is 7.88MPa.

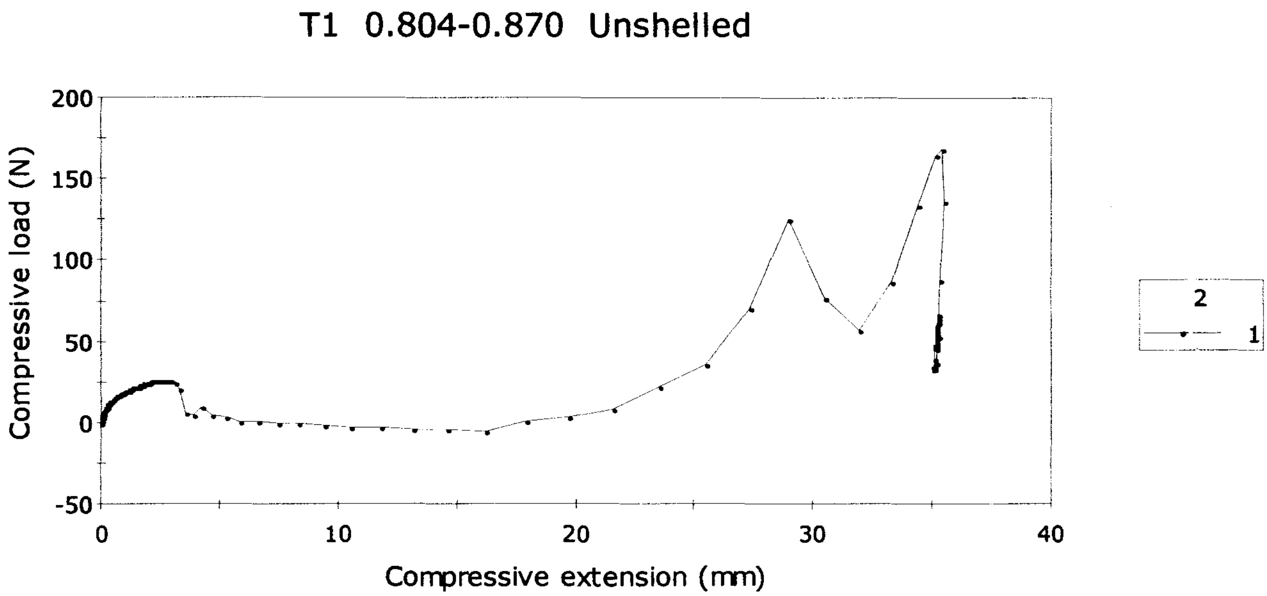

Fig 4.5: Force-deformation of the second unshelled seed

The Force-deformation curve of the third unshelled Jatropha curcas seed is shown in fig.4.6 below. From the graph, the initial portion of the curve from 0-20 (N) on the (load axes) is also steep and shorter than figs.4.4 and 4.5, indicating that the force required to rupture the shell or the nut is smaller. The line after the steep slope curves towards the force axes indicating that there is a decreased deformation as the load increases towards the kernel. The steep nature of the curve between 39.48N to 130.08 N, indicates a harder inner core of the kernel and a drop at 74.90 N, indicates that the little 'void' (empty space) in the centre of the nut is being closed up, the loading continues until the kernel ruptures at 109.96 N, (32.67 mm). The compressive extension and load at yield are 1.40mm and 17.52 N respectively. The compressive extension and load at rupture (break) are 31.82 mm and 35.73 N respectively. The Modulus automatically produced is 8.75 MPa.

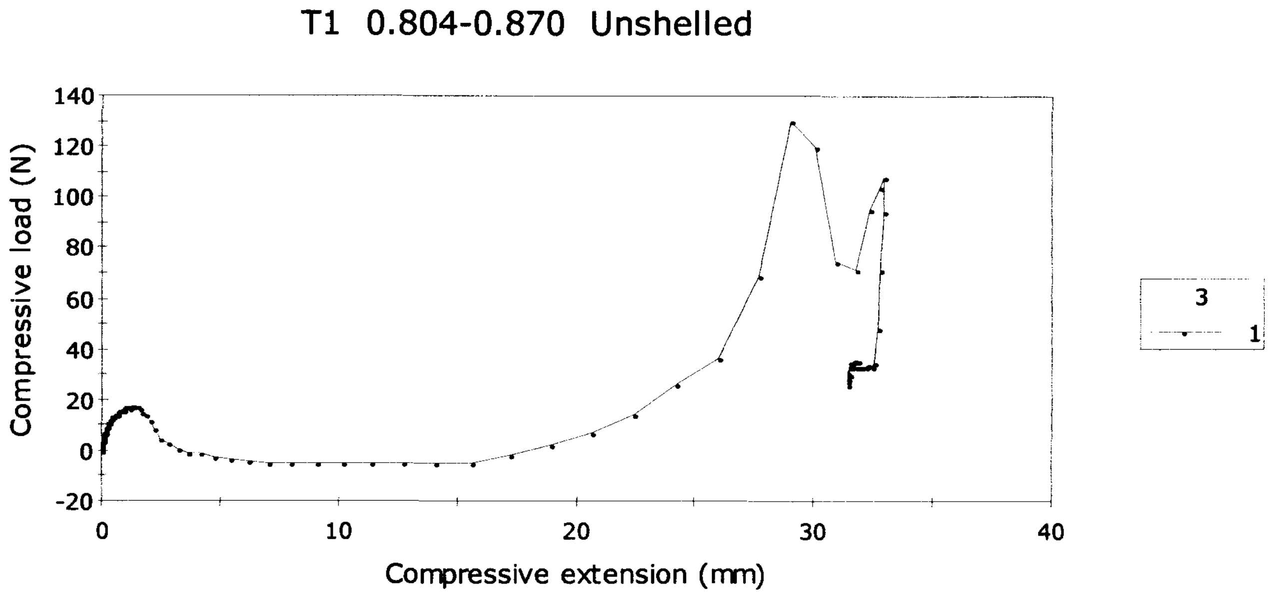

Fig.4.6: Force-deformation of the third unshelled seed

From the curves of the shelled seeds it could be seen that the initial part of the curve are concave towards the compressive extension (deformation) axes, indicating larger deformations in response to small force or load while the initial curve of the unshelled seeds are also concave to the deformation axes but with a very small deformation compared to that of the shelled seeds and this very small deformation is as a result of the empty or little space between the nut and the kernel. For the unshelled seeds, the initial portion of the curve (from zero to point of shell rupture) is steeper than that of the shelled seeds. This means that the curves of the unshelled agricultural materials are steeper than those of the shelled agricultural materials.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

A research has been made to determine engineering (rheological) properties of jatropha curcas seed both shelled and unshelled using Instron Universal Testing Machine (U.T.M).

The studies have shown from the graph that the compressive load and compressive extension of jatropha seed curve bend toward the x axis (deformation) indicating the relatively large deformation in response to initial small loading and the bending of curve toward the compressive loading axis also signifies that deformation decreases with increase in loading. It also shows that the force- deformation of shelled seed respond to small loading while unshelled seed required a larger force to deformed. More so agricultural materials always undergo a constant change in size, shape and mass as the moisture content decreases.

5.2 Recommendations

In considering how important were the engineering (rheological) properties are in designing of agricultural machine for handling, processing and transporting of the materials, the required instrument and equipment should be made available in our school laboratory to enable those, who will used this work as a foundation to undergo intensive research on bio-material.

REFFERENCES

Aderibigbe A.O Johson C.O Makkar H.P Becker K and Foidl N (1997) Chemical composition and effect of heat on organic mater and nitrogen degradability and some anti nutritional components of jatropha meal; Animal. feed science and technology volume 67 p 223-243

Akintayo E. T (2004) characteristic and composition of parkia biglobbossa and jatropha curcas oil and cakes. Bio-resource Technology volume 92 p 307-310

Biomass and Bio-energy v19 p1-19

DAFWA, Department of agriculture and food,WesternAustralia (2006) jatropha Banned in W.A Retrieved from www.agric.wa.gov.au

European journal of scientific Research ISSN 1450-216X Volume29 no 3 (2009) pp396-403. Retrieved from www.eurojournals. Com

Faborode M.O and Favier J.F(1996) identification and significance of the oil point in seeds oil expression journal of agricultural engineering Research volume65 p335-345

Fact foundation (2006) jatropha curcas handbook first draft from www.fact-fuel.org

Haas W and Mittelbach M (2000) detoxification experiment with the seed oil jatropha curcas L industrial crop and product volume12 p111-118

Henning R.K the jatropha website www.jatropha.org 1997-2004

Heller Joachim (1996) physic Nut jatropha curcas L IPGI-International plant Genetic

Journal of engineering science and technology volume 3 NO 2 (2008) at school of Engineering Taylors University College p 138-145.

J. Environ science Technology (2009) ISSN 1735 at IAU Development and evaluation of biodiesel fuel and by-product from jatropha oil volume 6(2) pp219-224.

Openshaw,W.K (2000) A review of jatropha curcas an oil plant of unfulfilled promise;

Sains Malaysiana (2008) physicochemical properties of Malaysian jatropha curcas seed oil volume 37 (4) pp379-382.

Research journal of jatropha seed. Applied sciences engineering and technology first Edition 2009 volume 3 pp154-159.

Sirisomboon p. kitchaiya p, pholpho T Mahuttanyavanitch W. (2007).

APPENDICES

A1: Statistical analysis and Tabular representation of the Moisture content in (% d.b) of shelled Jatropha curcas seeds

Weight	Values
W, weight of can (g)	24.50
W_1, weight of can + sample before oven drying (g)	53.53
W_2, weight of can + sample after oven drying (g)	52.45
Weight of water removed= W_2- W_1	3.08
Weight of dry sample= W_2-Weight of can (g)	25.95
Moisture content (% d.b)	11.01

A2: Statistical analysis and Tabular representation of the Moisture content in (% d.b) of unshelled Jatropha curcas seeds

Weight	Values
W, weight of can (g)	23.41
W_1, weight of can + sample before oven drying (g)	43.41
W_2, weight of can + sample after oven drying (g)	41.86
Weight of water removed= $W_2 - W_1$	2.5
Weight of dry sample= W_2-Weight of can (g)	18.45
Moisture content (% d.b)	13.60

A3: Statistical analysis and tabular representation of some Rheological properties at Yield (zero slope) for shelled Jatropha curcas seeds

S/N	Compressive extension at yield (mm)	Compressive load at yield (N)	Energy a t yield (J)	Compressive stress at yield point (MPa)	Compressive strain at yield point (mm/mm)
1	10.22937	36.51948	0.26462	0.97664	0.65784
2	9.40328	35.07098	0.23843	0.93791	0.60471
3	3.87047	27.07434	0.07760	0.72405	0.24890
Min	3.87047	27.07434	0.07760	0.72405	0.24890
Max	10.22937	36.51948	0.26462	0.97664	0.65784
Mean	7.834373	32.88826	0.19355	0.87953	0.50381
St.dev	3.457600	5.086830	0.101265	0.13603	0.22356

A4: Statistical analysis and tabular representation of some Rheological properties at Yield (zero slope) for unshelled Jatropha curcas seeds

S/N	Compressive extension at yield (mm)	Compressive load at yield (N)	Energy a t yield (J)	Compressive stress at yield point (MPa)	Compressive strain at yield point (mm/mm)
1	5.37266	123.23690	0.29313	1.83784	0.27496
2	2.20734	26.11214	0.04123	0.38941	0.11297
3	1.40453	17.52156	0.01922	0.26130	0.07188
Min	1.40453	17.52156	0.01922	0.26130	0.07188
Max	5.37266	123.23690	0.29313	1.83784	0.27496
Mean	2.99484	55.62353	0.11786	0.82951	0.15327
St.dev	2.09800	58.71222	0.15218	0.87557	0.10737

A5: Statistical analysis and Tabular representation of some Rheological properties at rupture (break) point of shelled seeds

S/N	Compressive extension at rupture (mm)	Compressive load at rupture (N)	Compressive strain at break (mm/mm)	Compressive stress at break (MPa)	Energy at break (J)	Modulus (MPa)
1	34.8567	53.10309	2.24159	1.42014	1.23735	2.50304
2	31.7282	54.68737	2.04040	1.46251	1.06176	3.71618
3	29.8637	75.47224	1.92050	2.01836	0.89474	7.30102
Min	29.8637	53.10309	1.92050	1.42014	0.89474	2.50304
Max	34.8567	75.47224	2.24159	2.01836	1.23735	7.30102
Mean	32.1495	61.08756	2.06749	1.63367	1.06461	4.50674
St.dev	2.5230	12.48265	1.62250	0.33382	0.17132	2.49477

A6: Statistical analysis and Tabular representation of some Rheological properties at rupture (break) point of unshelled seeds

S/N	Compressive extension at rupture (mm)	Compressive load at rupture (N)	Compressive strain at break (mm/mm)	Compressive stress at break (MPa)	Energy at break (J)	Modulus (MPa)
1	42.4987	398.28061	2.17496	5.93957	3.48031	10.37815
2	35.2315	66.48058	1.80305	0.99143	1.02622	7.88322
3	31.8215	35.73560	1.62853	0.53293	0.65386	8.74985
Min	31.8215	35.73560	1.62853	0.53293	0.65386	7.88322
Max	42.4987	398.28061	2.17496	5.93957	3.48031	10.37815
Mean	36.5172	166.83226	2.06039	2.48797	1.72013	9.00374
St.dev	5.45348	201.02876	6.03215	2.99794	1.53568	1.26669s

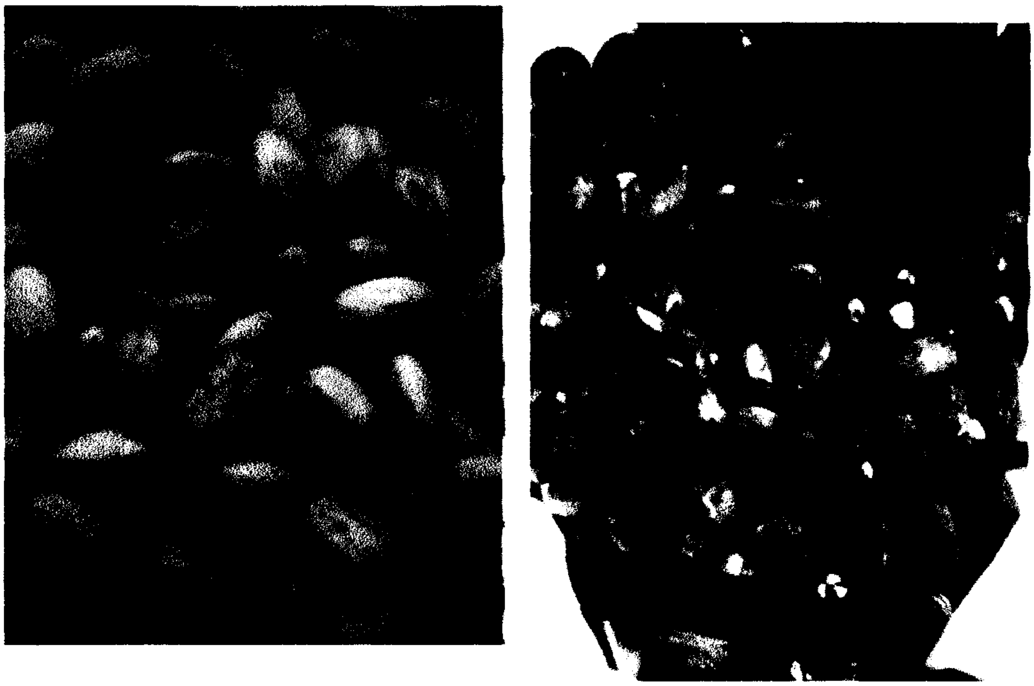

Plate 2.3 Shelled and Unshelled Jatropha seed (Heller, 1996)

Plate 2.4 Instron ` Universal testing machine (U.T.M)