EXTRACTION OF OIL FROM *JATROPHA CURCAS* SEED FOR THE PRODUCTION OF BIODIESEL

BY

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

JANUARY, 2011

DECLARATION PAGE

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 Information derived from personal communications, published and unpublished work were duly referenced in the text.

Igwe, Kingsley Onyebuchi

18/11/2011
Date

CERTIFICATION

This is to certify that the project, "Extraction of Oil from (*Jatropha curcas)* Seed for the Production of Biodiesel" by Igwe, Kingsley Onyebuchi 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.

Engr. Dr. P.A. Idah — 13/01/11
Supervisor — Date

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Head of Department — Date

External Examiner — 13/01/2011
Date

DEDICATION

This project work is dedicated to Almighty God who is the author and the finisher of our faith for his grace, mercy and for a dream come true.

I also dedicate this to the entire members of the Igwe's family for their love, understanding, care and support.

ACKNOWLEDGEMENTS

I give God almighty all the glory, praise and adoration for he is the author and finisher of our faith, the beginning and the end. He alone has made this project successful through thick and thin, his grace and mercies has been my strength and source of inspiration.

My profound gratitude goes to my supervisor Engr. Dr. P.A. Idah for his immense contribution to the success of this project. I also thank Engr. Dr. O. Chukwu for his contribution to the success of this project and my special thanks goes the HOD of Agricultural and Bioresources engineering Engr. Dr. A.A. Balami and to the entire lecturers and staff in the department for all the knowledge they have imbibed in me for the past five years.

I also wish to thank specially my lovely parents for their immense support both financially, morally and spiritually throughout this my academic pursuit. I also apprreciate my uncles, aunties, cousins, nephews, nieces, friends, course mates and well wishers whom are too numerous to mention here because of the constraints of space. I highly appreciate their concerted efforts towards the completion of this project work. I love you all, thank you so much and may God bless you all.

ABSTRACT

In this study oil was extracted from *jatropha curcas* seed and converted to biodiesel through transesterification and purified. Physical characteristics of the biodiesel produced were compared with the conventional diesel fuel. The results showed that the following properties were obtained: the specific gravity (0.881), viscosity (5.82 mm^2/s), flash point (96 ^0C), cloud point (-9 ^0C), pour point (-11 ^0C), water content (0.017 vol %), density (7.020), spread point (fast), flammability test (Non-sooty flame) and refractive index (1.499), The corresponding values of these properties for the conventional diesel are; specific gravity (0.848), viscosity (2.96mm^2/s), flash point (84.0), cloud point (-13 ^0C), pour point (-20 ^0C), water content (0.05max vol %), density (7.079 kg/m^3), spread point (faster), flammability test (sooty flame), and refractive index (1.664). It was concluded that biodiesel is better used when blended with conventional diesel.

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CHAPTER ONE

1.0 INTRODUCTION

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. 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 researches had been considered on the use of vegetable oils to produce biodiesel (Pramanik, 2003; Bozbas, 2005). One of such researchers lead to the discovery of oil extraction from jatropha curcas seed.

A specie of unshelled *jatropha carcus* seeds is shown in plate 1.0.

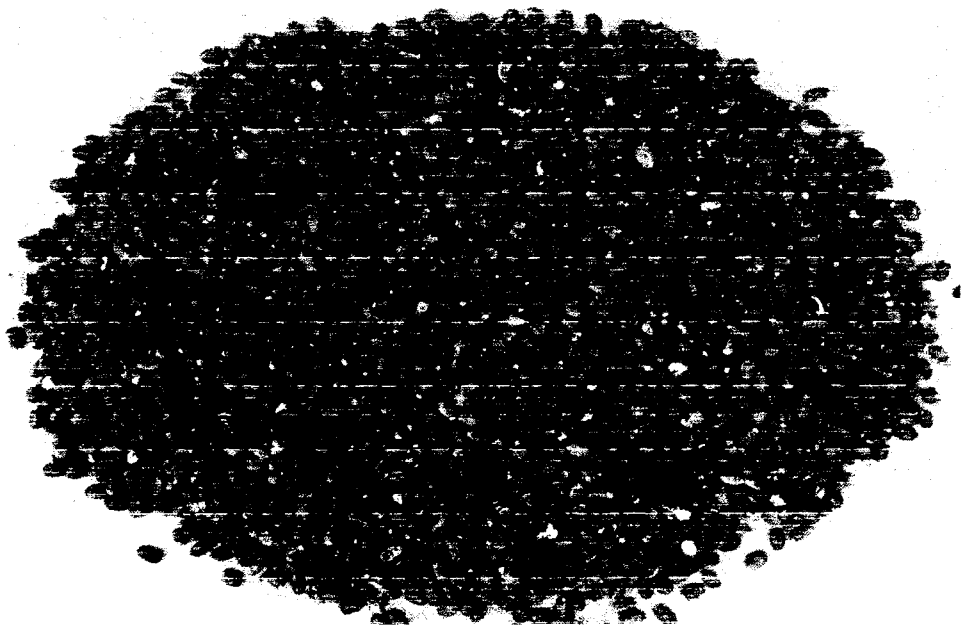


Plate 1.0: Unshelled *jatropha curcas* seed.

1.1 Background to the Study

The effect of environmental pollution resulting from consumption of non-renewable natural energy resources, calls for alternative energy as a substitute to the traditional fossil fuels. 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 lipid feed stock, such as vegetable oil or animal fat (Ma and Hanna, 1999; Van Gerpen, 2005; Wang *et al.*, 2006). Conversion of the oils to their alkyl esters reduced the viscosity to near the diesel fuel levels and produced a fuel with properties similar to petroleum based diesel fuels 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 due less smoke and particulates, higher cetane numbers and lower carbon monoxide and hydrocarbon emissions (Antolin *et al.*, 2002; Encinar *et al.*, 2007).

1.2 Statement of the Problem

Diesel is the major fuel used in vehicles such as trucks and trains. There is a growing demand for transportation fuel in most countries especially the current world energy crisis. It is important to explore the feasibility of substituting diesel from fossil fuel with an alternative fuel that can be produced on a massive scale for commercial utilization. The non-edible vegetable oil of *jatropha curcas* promises a commercially viable alternative.

1.3 Objectives of Study

The aim of this project is to synthesize biodiesel from *jatropha curcas* seed oil through the process of transesterification. The specific objectives of the research work are:

1 To extract oil from *jatropha curcas* seed.

2 To determine the properties of the extracted oil from *jatropha curcas* seed.

3 To determine the properties of the biodiesel produced from the extracted *jatropha curcas* oil and compare with the one obtained from diesel oil.

1.4 Justification of the Study

The rising world crude oil price, the growing environmental awareness and the fast depleting finite fossil fuel reservoirs has spurred renewed research interest and advances in alternative fuel development from agricultural feed stocks. At present, priority attention is being given to biodiesel derived from sources (such as; *Jatropha curcas,* waste vegetable oil, straw, and algae) that do not compete for food. This choice is informed by the argument that biodiesel produced from edible seed crops exacerbates global food crisis (Moore, 2008; Holmes, 2008; Ejilah *et al.* 2009).

1.5 Scope of the Study

The work will be focused on production of biodiesel using *jatropha curcas* oil with sodium hydroxide and methanol as catalyst and solvent, and the characterization of biodiesel produced respectively.

CHAPTER TWO

2.0 LITERATURE REVIEW

Biofuels are considered in part, a solution to such issues as sustainable development, energy security and a reduction of greenhouse gas emissions. Biodiesel, an environmental friendly diesel fuel similar to petro-diesel in combustion properties, has received considerable attention in the recent past worldwide. Biodiesel is a methyl or ethyl ester of fatty acid made from renewable biological resources such as vegetable oils (both edible and non edible), recycled waste vegetable oil and animal fats (Demirbas, 2000; Kinney and Clemente, 2005; Wilson *et al.*, 2005). 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 monoalkyl 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 use of vegetable oils as alternative fuels has been around since 1900 when the inventor of the diesel engine Rudolph Diesel first tested peanut oil in his compression ignition engine (Shay, 1993). However, due to cheap petroleum products such non-conventional fuels never took off until recently. Biodiesel derived from surplus edible oils like soybean, sunflower and rapeseed oils is already being used in USA and Europe to reduce air pollution, dependence on depleting fossil fuel localized in specific regions of the world and increases in crude oil prices (Ma and Hanna, 1999; Sarin *et al.*, 2007; Ranganathan *et al.*, 2008; Agarwal, 2007; Berchmans and Hirata, 2008; Foidl *et al.*, 1996; Openshaw, 2000; Meher *et al.*, 2006). The use of edible oil to produce biodiesel in Africa and other developing continents is not feasible in view of a huge gap between demand and supply of such oils in the developing world. There is therefore, need to explore alternative non-edible oil for use in production of biodiesel. However, in Asia and Africa, which are mostly net importers of vegetable oil, *Jatropha curcas* has been recognised as new energy crop for the countries to grow their own renewable energy source with many promising benefits. With the growing interest in biofuels worldwide, there is need for national governments in Africa to develop mechanisms for harnessing the potential of the fast growing industry and benefit from the growing international trade in biofuels. If Africa takes the lead in the production of biofuel, particularly from *Jatropha*, the continent's efforts in this endeavour will position it as an exporter of biodiesel, thus increasing its economic and political leverage in the global society. Many multinational companies, particularly Scandinavian, Chinese, European and Indian ones are scrambling for African land for *Jatropha* plantations. It is also reported that wireless communication giants Ericsson, GSMA and MTN are investing in using biofuel from *Jatropha* and other oils to power cellular network base stations in the developing world for the untapped market of the potential mobile users (Katembo and Gray, 2007).

The *jatropha curcas Linnaeus* plant originated from Mexico and spread to Asia and Africa through Portuguese traders as a hedge plant. *Jatropha curcas* belongs to the family *Euphorbiaceae*, which is renowned for having species that contravene the Geneva conventions on chemical warfare. The genus name *Jatropha* derives from the Greek *jatros* (doctor), *trophe* (food), which implies medicinal uses, hence the plant is traditionally used for medicinal purposes. It is a hardy shrub that can grow on poor soils and areas of low rainfall (from 250 mm a year) and is being promoted as the ideal plant for small farmers (Sarin *et al.*, 2007; Foidl *et al.*, 1996; Gressel, 2008). Since *Jatropha* can grow relatively well in marginal areas compared to other traditional crops, it may help to reclaim degraded land and protect the soil from soil erosion. The trees are easy to establish (from seeds or cuttings), grow relatively quickly (producing seed after their second year) and are hardy to drought. On the average, each mature tree produces about four kilograms of seed per year when cultivated under optimal conditions. It has a long productive period of around 30 - 50 years (Banapurmath *et al.*, 2008; Tamalampundi *et al.*, 2008).

The proximate analysis of *Jatropha* seeds revealed that the percentage of crude protein, crude fat and moisture were 24.60, 47.25 and 5.54% respectively (Akintayo, 2004). The seeds can be transported without deterioration and at low cost due to its high specific weight. The seeds of *Jatropha* contain 30 - 40% oil that can easily be expressed for processing biodiesel (Akintayo, 2004; Gubitz *et al.*, 1999; Mahanta *et al.*, 2008). *Jatropha curcas* gives higher oil yield per hectare than peanuts, sunflower, soya, maize or cotton when grown under optimum conditions. The processed oil can be used directly in diesel engines after minor modifications or after blending with conventional diesel. The fact that the oil of *jatropha curcas* cannot be used for nutritional purposes without detoxification makes its use as an energy source for fuel production very attractive. The byproducts of the biodiesel processing plant are nitrogen-rich press cake and glycerol, which are said to have good commercial

value as fertiliser and as a base for soap and cosmetics, respectively. Makkar *et al.* (1998) reported that *jatropha curcas* variaties contained substantial amount of crude protein. They also found that the amino acid composition of meals of non-toxic variety and toxic varieties was high and similar and the levels of essential amino acids except lysine were comparable with that for FAO reference protein. *Jatropha curcas* is traditionally used for medicines and as hedges to protect fields and gardens since animals do not eat it (Gubitz *et al.*, 1999; Mampane *et al.*, 1987; Joubert *et al.*, 1984; Staubamann, *et al.*, 1999). The leaves, root and bark also have potential for numerous other industrial and pharmaceutical uses. A number of enzymes such as protease, lipase and esterase with good properties for use in biotechnology have also been extracted and purified from *jatropha curcas* (Staubamann *et al.*, 1999; Nath *et al.*, 1991). These features have generated a great interest in the *Jatropha* plant which is now becoming a cash crop in South and Central America, Europe, Africa and Asia.

The positive claims on *jatropha curcas* are numerous, but only a few of them can be scientifically sustained. Information on cultivation, establishment, management and productivity of *Jatropha* under various climatic conditions is lacking in peer-reviewed literature. *Jatropha curcas* belongs to the family *Euphorbiaceae*, which is renowned of having species that contravene the Geneva conventions on chemical warfare. Research has indicated that *jatropha curcas* oil-producing seeds are toxic to humans and most animals and birds hence it is commonly referred to as "Black vomit nut", "Purge nut", "Physic nut", "Pinoncillo", "American purging nut", "Barbados purging nut", "poison nut tree" the "graveyard tree", etc (Akintayo, 2004; Gubitz *et al.*, 1999). *Jatropha curcas* is actually a tree known by more than 200 multi-language names (Katembo and Gray, 2007). Its oil is commonly known as hell oil, oil infernale (Makkar, *et al.*, 1998; Gubitz, *et al*, 1999; Staubamann *et al.*, 1999). Indeed the seed and/ oil were found to be toxic to mice (Adams, 1974), rats (Liberalino *et al.*, 1988), calves, sheep and goats (Ahmed and Adam, 1979a, b),

humans (Rai and Lakhanpal, 2008; Mampane *et al.*, 1987; Abdu-Aguye *et al.*, 1986; Koltin *et al.*, 2006), chickens (Samia *et al.*, 1992). Recent *jatropha curcas* poisoning in pediatric patients was reported in Mauritius where a total of eleven cases of pignon *d'Inde* poisoning due to consumption of *Jatropha* seeds was reported in one day (Rai and Lakhanpal, 2008). Toxicity of *jatropha curcas* seeds is generally attributed to the presence of lectin in these seeds (Samia *et al.*, 1992). The fruits contain irritants which affect pickers and those who remove the seeds by hand. However, similar lectin values found in non-toxic Mexico and the toxic Cape Verde and Nicaragua varieties suggested that lectin is not the main toxic principle in *Jatropha* seeds (Makkar *et al.*, 1998). The seeds are poisonous because they contain toxalbumine called curcine, cyanic acid related to ricinic acid, and toxic phorbol esters (Nath and Dutta, 1991; Adolf *et al.*, 1984; Levin *et al.*, 2000; Rai and Lakhanpal, 2008). Toxicoses are reported in the medical literature and ingesting four seeds can be toxic to a child, with symptoms resembling organophosphate insecticide intoxication, yet with no antidote for the lethal mixture (Abdu-Aguye *et al.*, 1986; Gubitz *et al.*, 1999; Joubert *et al.*, 1984; Koltin *et al.*, 2006). Phorbol esters were found to be responsible for purgative, skin-irritant effects and tumour promotion (Adolf *et al.*, 1984; Hirota *et al.*, 1988). The leaves contain the flavonoids apigen and its glycosides vitexin and isovitexin, the sterols stigmasterol, β-D-sitosterol and its β-D-glucoside (Mampane *et al.*, 1987). In addition, *jatropha curcas* leaves contain steroid sapogenins, alkaloids, the triterpenalcohol 1-triacontanol (C30H62O) and a dimmer of a triterpenalcohol (C63H117O9). 12-Deoxy-10-hydroxyphorbol, a polyunsaturated diterpene ester was isolated from the seed oil of *jatropha curcas* which is an irritant and purgative (Adolf *et al.*, 1984).

The extraction of biocrude oil from the *Jatropha* seeds is expected to generate huge quantities of residual deoiled seed cake. Jatropha production is forecasted at about 2500 kg seeds per hectare under Indian conditions (Hirota *et al.*, 1988). Considering 40 - 50% oil in

the seeds, the extraction will generate approximately 1000 kg seed cake per hectare crop. The *jatropha curcas* nitrogen-rich press cake by-product is very toxic and cannot be used as animal feed without first having been detoxified. The toxicity of *jatropha curcas* is based on several components such as phorbol esters, curcains, trypsin inhibitors and others that are present in considerable amounts in all plant components which make complete detoxification a difficulty and complicated process. The best extraction procedures available for the removal of phorbol esters remove about half, which is unacceptable toxicologically in accessions with high initial content (Haas and Mittelbach, 2000; Martinez *et al.*, 2006; Makkar *et al.*, 1997). Detoxification has only been successful at laboratory scale but since the process is complicated, it is not suitable for small and large scale and local use. For animal feed, the seed cake must be detoxified completely, and constantly with quality guaranteed and therefore, it is expected to be expensive. If the seed cake could be detoxified and used as animal feed, the benefits of the *Jatropha* projects will be increased significantly (Mahanta *et al.*, 2008).

2.1 Processing Techiques

Natural vegetable oils and animal fats are pressed to obtain crude oil which contains free fatty acids, phospholipids, sterols, water, odorants and other impurities (Openshaw, 2000). As a result of high viscosity, low volatility and the polyunsaturated character of the vegetable oils, they cannot be used as fuel directly in compression engines (Banapurmath *et al.*, 2008; Srivastava and Prasad, 2000). The specifications of the seed oil of *jatropha curcas* are outlined in Table 2.1 and the fatty acid composition of the seed oil of *jatropha curcas* is compared with other vegetable oils in Table 2.2 *Jatropha* seed oil has about 72% unsaturated fatty acids with oleic acid predominantly followed by lenoleic acid. The viscosity of *Jatropha* oil is considerably lower than those reported for some common and tested oils at 30°C such as soybean (31cSt), cottonseed (36cSt), and sunflower (43cSt) and pointing to its suitability

for use as diesel fuel (Akintayo, 2004; Kamman and Phillip, 1985). To overcome the problems highlighted above of using the vegetable oils directly, the oils require chemical modification so that they can match the properties of fossil diesel. The processing techniques that are mainly used to convert vegetable oils including *Jatropha* oil into fuel form are direct use and blending, pyrolysis, micro emulsification and transesterification (Demirbas, 2000; Ma and Hanna, 1999; Nwafor, 2003). Although production of biodiesel is a mature technology, there is still a lot of ongoing research to improve the quality and yield of the biodiesel from vegetable oils.

Table 2.1 Specifications of the seed oil of *jatropha curcas* (Foidl *et al.*, 1996; Tamalampundi *et al.*, 2008).

Variable	Variety Caboverde	Variety Nicaragua	Variety Nigeria
Colour	Light yellow	Light yellow	Light yellow
Saponification number (mg/g)	192	190	199
Viscosity at 30°C	39	37	17
Free fatty acids (% weight)	0.3-0.4	6-1.3	1.8
Unsaponifiable (% weight)	1.1	0.8	0.8
Iodine number	95	107	105
Acid value	-	-	3.5
Specific gravity (25°C)	-	-	0.92

Source: *Jatropha curcas* as a resource for the production of biofuel in Nicaragua. Bioresour. Technol., 58: 77-82 and Enzymatic production of biodiesel from *Jatropha* oil: A comparative study of immobilized-whole cell and commercial lipases as a biocatalyst. Biochem. Eng., J. 39: 185-189.

Table 2.2 Fatty acid composition (%) of the seed oil of *jatropha curcas* compared with other vegetable oils (Ma and Hanna, 1999; Sarin *et al.*, 2007; Foidl *et al.*, 1996).

Fatty acid	*J. curcas* Caboverde	*J. curcas* Nicaragua	Soybean	Cotton seed	Palm	Sunflower
Capric	0.1	0.1	–	–	–	–
Myristic	0.1	0.1	0.1	0.7	1.0	0.2
Palmitic	15.1	13.6	10.2	20.1	42.8	4.8
Palmtoleic	0.9	0.8	0.1	–	-	0.8
Stearic	7.1	7.4	3.7	2.6	4.5	5.7
Oleic	44.7	34.6	22.8	19.2	40.5	20.6
Linoleic	31.4	43.2	53.7	55.2	10.1	66.2
Linolenic	0.2	0.2	8.6	0.6	0.2	0.8
Arachidic	0.2	0.3	0.3	–	0.4	-
Behenic	0.2	–	0.1	–	–	–
Lauric	–	-	0.1	0.1	0.1	0.5

Source: Biodiesel Production: a review. Bioresour. Technol., 70: 1-15, *Jatropha*-Palm biodiesel blends: An optimum mix for Asia. Fuel 86: 1365-1371 and *Jatropha curcas L.* as a resource for the production of biofuel in Nicaragua. Bioresour. Technol., 58: 77-82.

2.2 Direct Use and Blending

In 1900 Dr Diesel demonstrated his engine running on 100% peanut oil at World Exhibition in Paris. Caterpillar (Brazil) in 1980 used pre-combustion chamber engines with a mixture of 10% vegetable oil to maintain total power without any modifications to the engine (Agarwal, 2007). A mixture of degummed soybean oil and No. 2 diesel fuel in the ratio 1:2 did not cause lubricating oil thickening and gelling unlike a 1:1 ratio when tested for engine performance and crankcase lubricant viscosity in a John Deere 6-cylinder, 6.6 L displacement, direct-injection, turbo charged for a total 600 h (Adams *et al.*, 1983).

Pramanik *et al.* (2003) found that 50% blend of *Jatropha* oil could be used in diesel engine without any major operational difficulties but further study is needed on the long term effect on engine. However, direct use of vegetable oils and their blends have generally been considered to be unsatisfactory and difficult to use in both direct and indirect diesel engines. The obvious problems are the high viscosity, acid composition, free fatty acid content, as well as gum formation due to oxidation, polymerisation during storage and combustion, oil ring sticking, carbon deposits and thickening or gelling of lubricating oil and other problems (Ma and Hanna, 1999; Agarwal, 2007; Meher *et al.*, 2006).

2.3 Micro - Emulsion

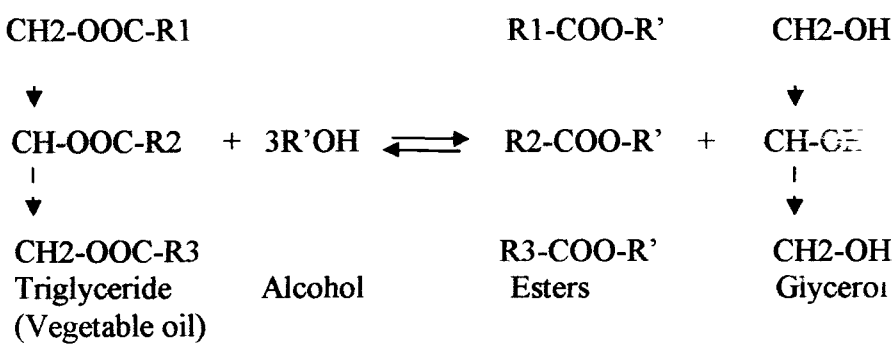
The problem of the high viscosity of vegetable oils was solved by micro-emulsions with solvents such as methanol, ethanol, and 1-butanol (Agarwal, 2007). A micro emulsion is defined as a colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the 1 - 150 nm range formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles (Ma and Hanna, 1999). The components of a biodiesel micro- emulsion include diesel fuel, vegetable oil, alcohol, and surfactant and cetane improver in suitable proportions. Alcohols such as methanol and ethanol are used as viscosity lowering additives, higher alcohols are used as surfactants and alkyl nitrates are used as cetane improvers. Micro emulsions can improve spray properties by explosive vaporisation of the low boiling constituents in the micelles. Micro-emulsion results in reduction in viscosity increase in cetane number and good spray characters in the biodiesel. According to Srivastava and Prasad (2000), short term performance of micro-emulsions of aqueous ethanol in soybean oil was nearly as good as that of No. 2 diesel, despite the lower cetane number and energy content. However, continuous use of micro-emulsified diesel in engines causes problems like injector needle sticking, carbon deposit formation and incomplete combustion.

2.4 Pyrolysis (thermal cracking)

Pyrolysis can be defined as the conversion of one substance into another by means of heat in the absence of air (or oxygen) or by heat in the presence of a catalyst which result in cleavage of bonds and formation of a variety of small molecules. The pyrolysis of vegetable oil to produce biofuels has been studied and found to produce alkanes, alkenes, alkadienes, aromatics and carboxylic acids in various proportions (Ma and Hanna, 1999; Alencar *et al.*, 1983; Peterson, 1986). The equipment for thermal cracking and pyrolysis is expensive for modest biodiesel production particularly in developing countries. Furthermore, the removal of oxygen during the thermal processing also removes any environmental benefits of using an oxygenated fuel (Ma and Hanna, 1999). Another disadvantage of pyrolysis is the need for separate distillation equipment for separation of the various fractions. Also the product obtained was similar to gasoline containing sulphur which makes it less ecofriendly (Ranganathan *et al.*, 2007).

2.5 Transesterification (alcoholysis)

Transesterification of vegetable oils is the most popular method of producing biodiesel. Transesterification (alternatively alcoholysis) is the reaction of a fat or oil (trigylceride) with an alcohol to form fatty acid alkyl esters (valuable intermediates in oleo chemistry), methyl and ethyl esters (which are excellent substitutes for biodiesel) and glycerol as shown:



Transesterification as an industrial process is usually carried out by heating an excess of the alcohol with vegetable oils under different reaction conditions in the presence of an inorganic catalyst. The reaction is reversible and therefore excess alcohol is used to shift the equilibrium to the products side. The alcohols that can be used in the transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol, with methanol and alcohol being frequently used. The reactions are often catalysed by an acid, a base or enzyme to improve the reaction rate and yield. Alkali-catalysed transesterification is much faster than acid-catalysed transesterification and is most often used commercially (Ma and Hanna, 1999; Ranganathan *et al.*, 2008; Agarwal and Agarwal, 2007). The alkalis which are used include sodium hydroxide, potassium hydroxide, and carbonates. Sulphuric acid, sulfonic acids, and hydrochloric acids are the usual acid catalysts. After transesterification of trigylcerides, the products are a mixture of esters, glycerol, alcohol, catalyst and tri-, di- and monogylcerides which are then separated in the downstream (Ma and Hanna, 1999; Freedman *et al.*, 1986; Demirbas, 2005).

The process of transesterification brings about drastic change in viscosity of the vegetable oil. The high viscosity component, glycerol, is removed and hence the product has low viscosity like the fossil fuels. The biodiesel produced is totally miscible with mineral diesel in any proportion. Flash point of the biodiesel is lowered after transesterification and the cetane number is improved. The yield of biodiesel in the process of transesterification is affected by several process parameters which include; presence of moisture and free fatty acids (FFA), reaction time, reaction temperature, catalyst and molar ratio of alcohol and oil.

2.6 The Effect of Moisture and Free Fatty Acids

The gylceride should have an acid value less than 1 and all materials should be substantially anhydrous. An acid value greater than 1 requires that the process uses more sodium hydroxide to neutralise the free fatty acids. Transesterification yields are significantly

reduced if the reactants do not meet this requirement (Freedman *et al.*, 1986; Goodrum, 2002; Dorado *et al.*, 2002; Ma *et al.*, 1998). The presence of water causes the transesterification reaction to partially change to saponification, which produces soap and thus lowering the yield of esters. Saponification also renders the separation of ester and glycerol difficult since it increases the viscosity and form gels (Berchmans and Hirata, 2008).

Most of the biodiesel is currently made from edible oils by using methanol and alkaline catalyst. However, there are large amounts of low cost oils and fats that cannot be converted to biodiesel using methanol and alkaline catalyst because they contain high amounts of free fatty acids and water. In some instances, crude *jatropha curcas* oil quality gradually deteriorates due to improper handling and inappropriate storage conditions which cause various chemical reactions such as hydrolysis, polymerization and oxidation to occur. Improper handling and prolonged exposure of crude *jatropha curcas* oil will result in an increase in the concentration of free fatty acids and water. The presence of high concentration of free fatty acids can significantly reduce the yield of methyl esters. Two-step process, acid-catalysed esterification process and followed by base-catalysed transesterification process have been developed for these oils in which initially the free fatty acids are converted to fatty acid methyl esters by an acid catalysed pretreatment and then transesterified using alkaline catalyst in the second step (Berchmans and Hirata, 2008; Ghadge and Raheman, 2005; Velkovic *et al.*, 2006). A two-stage transesterification process for crude *J. curcas* L. seed oil with high content of free fatty acids was studied by Berchmans and Hirata (2008). The first stage was acid pretreatment process which reduced the free fatty level to less than 1%. The second stage, alkali base catalysed transesterification process gave 90% methyl ester yield.

2.7 The Effect of Reaction Time

The conversion rate increases with reaction time and therefore is important in the transesterification process. Freedman *et al.* (1986) studied the transesterification of peanut, cotton-seed, sunflower and soybean oils under methanol to oil ratio of 6:1, 0.5% sodium methoxide catalyst and 60°C. About 80% yield was observed after 1 minute for soybean and sunflower oils. After an hour, yields (93 - 98%) were almost the same for the four oils. Similar results were reported by Ma *et al.* (1998). No similar studies have been reported for *jatropha curcas* oil.

2.8 The Effect of Reaction Temperature

The transesterification process can occur at different temperature depending on the oil used. Generally the reaction is carried out close to the boiling point of methanol (60 - 70°C) at atmospheric pressure at molar ratio (alcohol to oil) of 6:1 (Srivastava and Prasad, 2000; Pramanik, 2003; Huaping *et al.*, 2006). Freedman *et al.* (1984) observed that temperature clearly influenced the reaction rate and yield of esters when they investigated transesterification of soybean oil with methanol (6:1) at 32, 45 and 60°C.

2.9 The Effect of Molar Ratio

The stoichiometric ratio for transesterification requires 3 mole of alcohol per mole of triglyceride to yield 3 mole fatty esters and 1 mole of glycerol. The transesterification reaction is shifted to the right by using excess alcohol or removing one of the products from the reaction mixture continuously. A molar ratio of 6:1 (with alkali as the catalysts) is normally used in industrial processes to obtain yields of methyl esters higher than 98% by weight. Ratios greater than 6:1 do not increase the yield but rather interfere with separation of glycerol because there is an increase in glycerol solubility. When glycerine remains in solution, it helps drive the equilibrium back to the left, lowering the yield of esters (Tomasevic and Marinkovic, 2003). When using acid catalyst the desirable product is

obtained with 1 mol% of sulphuric acid with molar ratio of 30:1 at 65°C and conversion of 99% is achieved in 50 h.

2.2.0 The Effect of Catalysts

To make the transesterification process possible a catalyst in the form of an alkali, acid or lipase enzyme is required.

2.2.1 Alkali Catalyst

Alkali-catalysed transesterification is much faster than acid-catalysed transesterification and is less corrosive to industrial equipment and therefore is the most often used commercially (Ma and Hanna, 1999; Ranganathan *et al.*, 2008; Agarwal, 2007; Marchetti *et al.*, 2007). Sodium hydroxide or potassium hydroxide is used as basic catalyst with methanol or ethanol as well as the vegetable oil. Sodium hydroxide is cheaper and is the widely used in large scale-processing. The alkaline catalyst concentration in the range of 0.5 - 1% by weight yield 94 - 99% conversion of most vegetable oils into esters. There are several disadvantages in using an alkaline catalysis process although it gives high conversion levels of triglycerides to their corresponding ,methyl esters in short reaction times. The process is energy intensive, recovery of glycerol is difficult, the alkaline catalyst has to be removed from the product, alkaline wastewater generated requires treatment and the level of free fatty acids and water greatly interfere with the reaction. The risk of free acid or water contamination results in soap formation that makes the separation process difficult (Fukuda *et al.*, 2001; Barnwal and Sharma, 2005).

2.2.2 Acid Catalyst

The second conversional way of making the biodiesel is to use the triglycerides with alcohol and an acid. Sulphuric acid, sulfonic acids, and hydrochloric acids are the usual acid catalysts but the most commonly used is sulphuric acid. Acid catalysts are used if the triglyceride has a higher free fatty acid content and more water. Although the yields could be

high, the corrosiveness of acids may cause damage to the equipment and the reaction rate can be low, sometimes taking more than day to finish (Freedman *et al.*, 1984). According to some authors, the reactions are also slow, requiring typically temperature above 100°C and more than 3 h to complete the conversion (Meher *et al.*, 2006). For example, Freedman *et al.* (1986) studied the transesterification of soybean oil in the presence of 1% sulphuric acid with alcohol/oil molar ratio 30:1 at 65°C and the conversion was completed in 20 h.

2.2.3 Heterogeneous Catalysts

Heterogeneous catalysts such as amorphous zirconia, titanium and potassium zirconias have also been used for catalysing the transesterification of vegetable oils. Huaping *et al.* (2006) demonstrated the potential of preparing biodiesel from *jatropha curcas* oil catalyzed by solid super base of calcium oxide and its good refining process. When treated with ammonium carbonate solution and calcinated at high temperature, calcium oxide becomes a solid super base, which shows high catalytic activity in transesterification. Under the optimum conditions, the conversion of *jatropha curcas* oil can reach 93%. The heterogeneous catalyst eliminates the additional cost associated with the homogeneous sodium hydroxide to remove the catalyst after transesterification.

2.2.4 Lipase Catalyst a Biotechnological Approach

Recently, enzymatic transesterification has attracted much attention for biodiesel production as it produces high purity product (esters) and enables easy separation from the by-product, glycerol (Devanesan *et al.*, 2007; Mamoru *et al.*, 2001; Oznur and Melek, 2002; Ranganathan *et al.*, 2008). The enzyme that was found to be capable of catalysing transesterification is lipase. Lipase can be obtained from microorganisms like *Mucor miehei*, *Rhizopus oryzae*, *Candida antarctica*, *Pseudomonas fluorescens* and *Pseudomonas cepacia*.

Enzymatic biodiesel production is possible using both intracellular and extracellular lipases. Biocompatibility, biodegradability and environmental acceptability of the

biotechnological procedure when using lipase as a catalyst are the desired properties in this alternative biodiesel production method (Marchetti *et al.*, 2007; Devanesan *et al.*, 2007). However, the use of extracellular lipase as a catalyst requires complicated recovery, purification and immobilisation processes for industrial application (Bank *et al.*, 2001). Consequently, the direct use of whole cell biocatalyst of intracellular lipases has received considerable research efforts (Devanesan *et al.*, 2007; Kaieda *et al.*, 1999; Matsumoto *et al.*, 2001). For the industrial transesterification of fats and oils, *Pseudomonas* species immobilised with sodium alginate gel can be used directly as a whole cell bio-catalyst (Foidl *et al.*, 1996; Devanesan *et al.*, 2007; Mohamed and Uwe, 2003; Yong and Siyi, 2007). Devanesan *et al.* (2007) reported maximum yield (72%) of biodiesel from transesterification of *Jatropha* oil and short chain alcohol (methanol on hexane) using immobilized *P. fluorescens* at the optimum conditions of 40°C, pH 7.0, molar ratio of 1:4, amount of beads of 3 g and reaction time of 48 h. In all the work in literature on lipases, the enzymes or whole cells are immobilised and used for catalysis. The advantage of immobilisation is that the enzyme can be reused without separation. Also the operating temperature of the process is low (50°C) compared to other techniques which operate at harsh conditions. However, the cost of enzymes remains a barrier for its industrial implementation (Neslon *et al.*, 1996; Shimada *et al.*, 2002). In order to increase the cost effectiveness of the enzymatic process, the enzyme (both intracellular and extracellular) is reused by immobilising in a suitable biomass support particle and that has resulted in considerable increase in efficiency (Ranganathan *et al.*, 2008, Neslon *et al*, 1996; Jackson and King, 1996).

Jackson and King (1996) used immobilised lipases as biocatalysts for transesterification of corn oil in flowing supercritical carbon dioxide and reported an ester conversion of more than 98%. But the activity of immobilized enzyme is inhibited by methanol and glycerol present in the mixture. The use of *tert*-butanol as a solvent, continuous

removal of glycerol, stepwise addition of methanol are found to reduce the inhibitory effects, thereby increasing the cost effectiveness of the process (Li *et al.*, 2006; Samukawa *et al.*, 2000; Royon *et al.*, 2007).

Effective methanolysis using extracellular lipase has been reported to improve by stepwise addition of methanol through which 90 - 95% conversion can be achieved even after 50 and 100 cycles of repeated operation (Shimada *et al.*, 2002; Samukawa *et al.*, 2000; Watanabe *et al.*, 2000). The efficiency of transesterifcation process using lipase can be significantly increased by using intracellular lipase (whole cell immobilisation) instead of extracellular lipase which demands complex purification stages before immobilisation. This can clearly reduce cost of the transesterification production as reported by Matsumoto *et al.* (2001), Ban *et al.* (2001) and Hama *et al.* (2004), when *R. oryzae* for the transesterification process of vegetable oils was used.

Tamalampudi *et al.* (2008) recently reported that whole cell *R. oryzae* immobilised onto bio-mass support particles which catalysed the methanolysis of *Jatropha* oil more efficiently than Novozym 435. The production of biodiesel using a biocatalyst eliminates the disadvantages of the alkali process by producing product of very high purity with less or no downstream operations (Meher *et al.*, 2006; Fukuda *et al.*, 2001; Modi *et al.*, 2007). The process of producing biodiesel using immobilised lipase has not yet been implemented at industrial scale. On the other hand, in general the production cost of a lipase catalyst is significantly greater than that of an alkaline one. There are no comparative studies in the literature on the most appropriate transesterification technique which can be used to produce biodiesel from *jatropha curcas*.

2.2.5 Fuel Properties of *Jatropha* Biodiesel

The fuel properties of *Jatropha* biodiesel has comparable properties with those of fossil biodiesel and conforms to the latest standards for biodiesel. Standardisation is a prerequisite for successful market introduction and penetration by biodiesel and many countries including Austria, Germany (DIN), Italy, France, and United States (ASTMD) have defined standards for biodiesel.

2.2.6 Application of Biodiesel in Combustion Engines

The properties of *Jatropha* oil, *Jatropha* biodiesel and fossil diesel are compared in Table 2.3 the high viscosity of vegetable oils leads to problems in pumping and spray characteristics when used in combustion engines. The best way to use the vegetable oils as fuel in compression ignition engines is to convert it into biodiesel. Biodiesel can be blended in various proportions with fossil diesel to create a biodiesel blend or can be used in its pure form. It can be used in compression ignition engines with very little or no engine modifications because it has properties similar to mineral diesel (Banapurmath *et al.*, 2008; Devanesan *et al.*, 2007). Vegetable oils offer almost the same power output with slightly lower thermal efficiency when used in diesel engines (Makkar *et al.*, 1997; Pramanik, 2003; Agarwal and Agarwal, 2007; Tiwari *et al.*, 2007). However, Banapurmath *et al.* (2008) reported that compared to the fossil diesel operation, biodiesel from *Pongamia pinnata* (Honge oil), *Jatropha curcas*, *Hevea brasiliensis* (rubber) and *Calophyllum inophyllum* resulted in poor performance associated with higher emissions, but on the whole it was seen that operation of the engine was smooth and existing engines could be operated with the biodiesel without any major modification.

Table 2.4 Fuel properties of *Jatropha* oil, *Jatropha* biodiesel and fossil diesel (Kamman and Phillip, 1985; Matsumoto *et al.*, 2001; Ban *et al.*, 2001).

Property	*J.* oil	*J.* biodiesel	Diesel	Biodiesel standards	
				AST D 6751-02	DIN EN 14214
Density (15°C, kgm-3)	940	880	850	–	860-900
Viscosity (mm2s-1)	24.5	4.8	2.6	1.9-6.0	3.5-5.0
Flash point (°C)	225	135	68	>130	>120
Pour point (°C)	4	2	–20	–	–
Water content (%)	1.4	0.025	0.02	<0.03	<0.05
Ash content (%)	0.8	0.012	0.01	<0.02	<0.02
Carbon residue (%)	1.0	0.20	0.17	-	<0.30
Acid value (mgKOHg-1)	28.0	0.40	–	<0.80	<0.50
Calorific value (MJkg-1)	38.65	39.23	42	–	–

Source: Sulfurized vegetable oil products as lubricants additives. J. Am. Oil Chem. Soc., 65: 883-885, Yeast whole-cell biocatalysts constructed by intracellular overproduction of *Rhizopus oryzae* lipase are applicable to biodiesel fuel production. Appl. Microbiol. Biotechnol., 57: 4-11, and Whole cell biocatalyst for biodiesel fuel production utilising *Rhizopus oryzae* cells immobilised within biomass support particles. Biochem. Eng., 8: 39-43.

The fact that the oil of *jatropha curcas* cannot be used for nutritional purposes without detoxification makes its use as energy source for fuel production very attractive. *Jatropha curcas* oil was used as a diesel fuel substitute during the Second World War in Madagascar, Cape Verde and Benin. Early engine tests with *jatropha curcas* oil were done in Thailand showing satisfactory engine performance. A 50 hours continuous test and starting experiments were conducted using transesterified *jatropha curcas* oil, No. 2 diesel fuel and their blends in two small pre-combustion-chamber – type diesel engine (Gubitz *et al.*, 1999; Recep *et al.*, 2000).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Materials

- *Jatropha curcas* seed

Reagents

- Methanol (CH_2 OH)
- Sodium Hydroxide (NaOH)
- Petroleum Ether (C_6 H_6)

Apparatus

- Soxhlet
- 500ml Beaker
- 500ml Measuring Cylinder
- Flash Point Tester
- Thermometer 200^0 C
- Magnetic Stirrer with Hot Plate
- Separating Funnel
- Viscometer
- pH Meter
- Weighting Balance
- Blending Machine
- Oven

3.2 Procedure for *Jatropha* Oil Extraction

Jatropha curcas seeds were cracked manually by hand and the shells were carefully removed before the seeds were grinded using a blender into a coarse particle size, and were dried in the oven at a temperature of 105^0 C.

1 15g of sample was taken each and were wrapped in a filter paper and inserted into the soxhlet chamber. This is shown in plate 3.1 below.

Plate 3.1 Grinded and Wrapped *Jatropha Curcas* seed after Oven Drying.

2 200ml of petroleum ether each was introduced into the flat bottom flask and heated for about six (6) hours at $40 - 60^0$ C.

3 As the heating continues the solvent evaporates into the soxhlet and it dissolves the fat in the sample inside the soxhlet chamber and reflux back to the flat bottom flask.

4 The oil was gotten by evaporating the solvent out in the flat bottom flask using water bath.

3.3 Methodology of Biodiesel Production

The following steps are involved in the production of biodiesel from *jatropha curcas* oil;

1 The free fatty acid level was determined using electronic pH meter in order to calculate the amount of caustic soda that would be required free fatty acid.

2. Mixing of alcohol and catalyst; for this process, a specified amount 5g of sodium hydroxide pellet was mixed with 50ml of methanol inside the strong heat resistance glass bottle with a narrow neck to prevent splashing (*Kjeldah* flask). Fume was produced and a mixture of sodium hydroxide and methanol was obtained after 30mins to produce methoxide ($NaOCH_3$). Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters.

3. The methyl ester mixture; In production of biodiesel, the methoxide solution with 100ml of *jatropha* oil were mixed properly using a magnetic stirrer while heating between 40 to 60° C for 90 mins in order to avoid evaporation of methanol in the mixture.

4. Separation of glycerin and biodiesel; once the reaction is complete two major products exist: glycerin and biodiesel, which was done by using a separation funnel where the glycerin will settle at the top and the biodiesel at the bottom and was allow standing for 24 hours to achieve full separation of the mixture. The quantity of produced glycerin varies according the oil used, the process used, and the amount of excess alcohol used both the glycerin and biodiesel products have a substantial amount of the excess alcohol that was used in the reaction. The raw biodiesel was washed with distilled water to remove some traces of soap and other contaminants and allowed the water settled down before removing by draining, the pH was 7 after little traces of water and gently evaporated on low heat.

5. The biodiesel yield was 60ml at the end of purification process while the jelly like residue was glycerin which was the by-product and which is useful by organic and chemical industries. The characterization, analysis and comparative test were carried out using a low sulphur content fossil (petroleum) diesel as the standard control according to Nadkarni (2003) and the American Standard Test Method for Diesel (ASTM-D).

In general biodiesel production from the transesterification reaction of *jatropha curcas* oil involves the use of methanol (CH_2OH) and the addition of sodium hydroxide (NaOH) as catalyst. The catalytic reaction rate increase with increase in temperature forming methoxide which eventually reacted with the oils in a process called transesterification thus producing biodiesel.

3.4 Characterization Procedure

The pure biodiesel obtained through the procedure was characterized to test for the following fuel physical properties:

3.4.1 Flash Point Determination

The flash point was determined using pensky-marten equipment. The apparatus consists of a small cup into which the sample was put in; the cup was gradually heated while being stirred to distribute heat uniformly in the cup and the temperature of the oil was monitored with a thermometer. At regular interval temperature, cup was exposed to naked flame. The temperature at which the oil catches fire was determined; the temperature at which this occurred is the flash point of the sample.

3.4.2 Relative Density Determination

The density of a sample is determined by measuring the mass and volume of the sample and it is given by the relation density = mass / volume. The materials needed for the analysis were density flask, weighing balance and cleaning material for each batch.

3.4.3 Procedure for Relative Determination

1. Firstly, the bottle and the stopper were weighed.
2. The bottle was cleaned with cleaning material (e.g. detergent) and then with some dilutes nitric acid and rinsed with water. Then the flask was cleaned with stream clean water.
3. The bottle was cleaned, dried and filled with biodiesel test sample. It was weighed making sure that the bottle is held by neck to prevent temperature alteration in it. The reading was recorded. Relative density = M_2-M / M_1-M

3.4.4 Viscosity Determination

The common fenske viscometer was used to determine the viscosity of sample. The sample was put in the viscometer so that it just conceded with the level of the upper mark on the viscometer. The fall of the tube to the lower mark was monitored using the stop watch and the viscosity was calculated.

3.3.5 Determination of Refractive Index

Refractive meter was used to determine the refractive index of the biodiesel produced, few drop of the sample were placed on the glass slide of the refractor meter. Water at 350° C was circulated around the glass slide to keep its temperature uniform. The refractor meter was viewed through the eye piece; the dark portion viewed was adjusted to be in intersection with the cross. At no parallax error the pointer of the scale pointed on the refractive index. The value was noted and recorded.

3.3.6 Determination of Color

The color is determined by visualization of the physical appearance of the biodiesel.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

The results of the study carried out and the biodiesel production from *jatropha* oil is presented thus:

4.1 Oil Extraction

The quantity of oil extracted from150g of *jatropha curcas* seed was 100ml. This result differs slightly from data in literature review (Akintayo, 2004; Gubitz *et al.*, 1999; Mahanta *et al.*, 2008). The results could be as a result of differences in variety or production practices.

Table 4.1: Analytical comparative studies on *jatropha curcas* oil produced.

Properties	*Jatropha Oil*	ASTMD Standard
Specific Gravity	0.92	0.91 – 0.93
Free Fatty Acid (FFA)	8.5	10 – 15
Acid Value	48	45 – 55
Saponification Value (SV)	204.65	190 – 215
Iodine Value	69.04	70 – 80
Moisture content	3.4	0.5 max.

Plate 4.1 below shows the oil extracted from *jatrohpa curcas* seed ready to be used for the production of biodiesel.

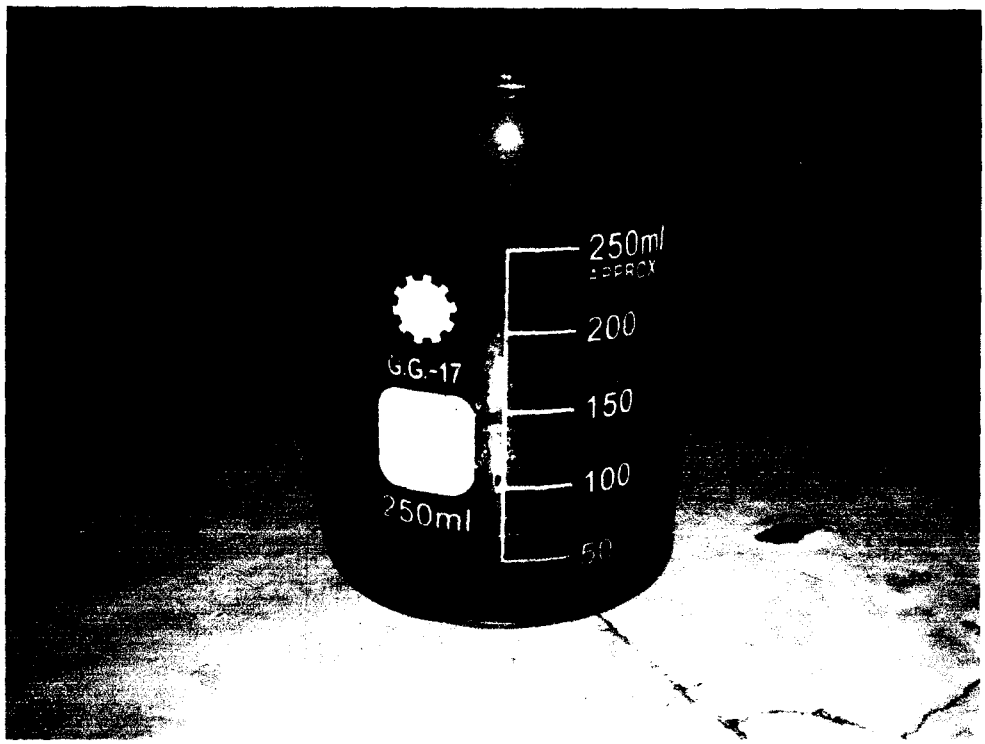


Plate 4.1 sample of extracted *jatrohpa curcas* oil.

4.2 Biodiesel Production

The results of the exercise shows that from the 100ml of *jatropha* oil used 60ml of biodiesel were produced. This result differs from other earlier studies (Ma and Hanna, 1999; Sarin *et al.*, 2007).

4.3 Properties of Biodiesel

The results of the analysis carried out on the produced biodiesel are shown in Table 4.2 shows the various properties of the biodiesel as compared to the conventional fossil fuel.

Table 4.2: Physical properties of conventional diesel and biodiesel produced from *jatropha* oil.

Parameter	Biodiesel	Conventional diesel	ASTMD
Specific gravity (kg/l)	0.881	0.848	0.872-0.906
Kinematic viscosity (mm^2/s)	5.82	2.96	1.9 - 6.5
Refractive index	1.499	1.664	1.245-1.675
Flammability	Non-sooty-flame	Sooty flame	Non-sooty flame
Spread point	Fast	Faster	Fast
Water content (vol %)	0.017	0.05 max.	0.05 max.
Flash point (°C)	96.0	84.0	90 – 100
Pour point (°C)	-11	-20	-35 - 20
Cloud point (°C)	-9	-13	-15 - 20
Density (kg/ m^3)	7.020	7.079	7.079-7.328

Plate 4.2 shows the funnel separation of biodiesel as it was carried out in the laboratory.

Plate 4.2 Funnel Separation of Biodiesel.

4.4 Discussion of Results

Table 4.1 describes that the physical and chemical properties of *jatropha* oil were comparable with ASTMD standard. The free fatty acid (FFA), 8.5 % as compared with American Standard Test Method (ASTMD) 10-15 this indicates the freshness of the oil which makes it to be better. The specific gravity (0.92) compared with 0.91- 0.93 of ASTMD. The iodine value, saponification value, acid value, free fatty acid, specific gravity, and moisture content were found to be 69.04, 204.65, 48, 8.5, 0.92, and 3.4 respectively which are within the specified limit.

Table 4.2 also presents the flash point of biodiesel was 96 ^{0}C. It was 4 $^\circ_C$ less than the limit of ASTMD standard and 12 ^{0}C higher than that of petrol diesel. This is due to higher flash point; biodiesel has certain advantages over petroleum diesel such as greater safety during storage handling and transportation. The pour point of biodiesel was -11 ^{0}C due to the unsaturated fatty acid content in *jatropha* oil but the result was found to be within the specified limit. Specific gravity, refractive index, density, and water content were found to be 0.881, 1.499, 7.020, 0.017 at 57.14 % recovery of biodiesel from *jatropha* oil were found to be within the ASTMD specified limit.

Viscosity; is another important property of biodiesel, biodiesel has higher viscosity than conventional diesel, though higher viscosity leads to poorer atomization of the fuel injectors but the viscosity (5.82 mm^2/s) of biodiesel was found within the ASTMD specified limit.

Colour; the color of the biodiesel produced was amber yellow while that of conventional fuel is translucent.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

At the end of this experimental research work, oil was extracted form *jatropha curcas* seed and the (chemical and physical) properties of the oil obtained were determined and that of the biodiesel produced were also determined. The result obtained revealed a 60% yield of biodiesel using the short chain alcohol (methanol) and 5g NaOH at optimum temperature values of 40 – 60 ^{0}C in 90 minutes reaction time.

A comparative analysis of the biodiesel produced with that of petroleum diesel shows that specific parameters such as; specific gravity 0.881 kg/1, flash point 96 ^{0}C, viscosity 5.82mm^2/s, refractive index 1.499, water content 0.017 vol %, pour point -11 ^{0}C, cloud point -9 ^{0}C, density 7.020 kg/m^3 of biodiesel indicating some advantages over the petroleum diesel; specific gravity 0.848 kg/1, flash point 84.0, viscosity 2.96mm^2/s, refractive index 1.664, water content 0.05max vol %, pour point -20 ^{0}C, cloud point -13 ^{0}C and density 7.079kg/m^3.

5.2 **Recommendations**

The following recommendations were made on the use of oil extract from *jatrohpa curcas* seed;

1. Since biodiesel can be locally produced on a large scale, community, private organization, cooperative group and individual are advised to embark on the production and the use of biodiesel in their community using *jatropha curcas* seed.
2. Biodiesel obtained from *jatrohpa curcas* seed should be readily accepted in the community since it causes less environmental pollution and will ultimately reduce dependence on importation of petroleum products.
3. It is highly recommended that the biodiesel sold in Nigeria should be industrially blended with 20% of conventional diesel for a start which it could be increased sequentially up to 100% in the near future similar to the United State America (USA) fiscal policy since the year 2001.
4. Apart from the oil content of *jatrohpa curcas* seed there are still other potentialities inherent in *jatrohpa curcas* seed like its medicinal values etc which can be fully exploited by the society.

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