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The challenge of biodiesel production from oil palm feedstock in Nigeria

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Research Article

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ABSTRACT

Nigeria has joined the league of countries seeking for alternatives to fossil fuels. Biofuel has emerged as a credible alternative and blend stock for the dwindling petroleum resources. Nigeria is committed to blending biodiesel with petrodiesel up to 20%. This paper evaluates the challenge of biodiesel production from oil palm feedstock in Nigeria. The study found that biodiesel production in Nigeria could be challenged by feedstock supply shortages, poor quality of the feedstock, technological challenges and poor policy framework. Oil palm in Nigeria is mostly processed by smallholders, producing oils of low quality due to high free fatty acid (FFA), moisture and impurities above limits for biodiesel production. Pretreatment techniques, which are used to upgrade the oil, could increase the cost of the resultant biodiesel. Because of the poor quality of the feedstock, enzymatic transesterification is a more feasible method for biodiesel production. The paper concludes by suggesting the use of inedible oil as feedstock, production of lipase for enzymatic transesterification and upgrading the Nigerian policy and incentives.

Keywords: biodiesel, biofuel, challenges, feedstock, microbial lipases, Nigeria.

INTRODUCTION

As the world population increases, the energy consumption also increases. In any nation, energy is the most fundamental requirement for human existence and activities (Ribeiro et al., 2011). Unfortunately, the non-renewable energy sources that contribute over 86% of the global energy supply (Atadashi et al., 2011) are depleting. Though, Nigeria is a major crude oil producing and exporting country, but due to corruption and mismanagement in the sector, petroleum products are in short supply in the country (Ohimain, 2010; 2012a, 2012b). Nigeria still depends on foreign nations for the supply of fuels. So it becomes exigent for Nigeria to explore other potential means of bettering her already pulverized economy (Oshewolo, 2012). Price hike in the depleting petroleum based products as well as greenhouse gas emission contributes significantly to climate change and ozone depletion. This problem has resulted to intense search for alternative feedstock and sustainable technology that can counter the shortcomings of non-renewable energy sources. Among the alternative energy considered to replace the dwindling conventional transportation fuel in Nigeria are biodiesel, straight-chain vegetable oil, bio-ethanol, bio-oil, bio-hydrogen, among other forms of biofuel that can be utilized in electricity and transportation fuel. Currently, agronomic efforts are made on increasing feedstock supply. Alternative feedstocks normally arise out of necessity from regions of the world where the materials are not locally available or as part of a concerted effort to reduce dependence on imported petroleum products (Moser, 2009).

Biomass has contributed significantly to the biofuel industry because most of oil used in the production of biodiesel is of plant origin. This is because vegetable oil has certain features that makes them attractive substitute for diesel fuels (Raja et al., 2011). Vegetable oil that has been intensively studied as raw materials for biodiesel production (Hasibuan et al., 2009) includes soybean oil, palm oil, castor oil, *Parkia biglobbossa, Jatropha curcas*, sunflower oil, coconut oil, rapeseed oil, safflower oil, ground nut oil, Neem oil, pea nut oil, oils, cotton seed oils, among others (Alamu et al., 2007; Aransiola et al., 2012; Akoh et al., 2007; Berchmans and Hirata, 2008; Robles-Medina et al., 2009). Other potential vegetable feedstock for biodiesel production includes Tobacco (*Nicotiana tabacum*), desert date (*Balanites aegyptiaca*), castanhola (*Terminalia catappa*), rubber tree (*Hevea brasiliensis*), tung (*Vernicia fordii*), milkweed (*Asclepias syriaca*), Zanthoxylum bungeanum, radish (*Raphanus sativus*), Ethiopian or Abyssinian mustard (*Brassica carinata*), false flax or gold-of-pleasure (*Camelina sativa*), Polanga (*Calophyllum* *inophyllum*), Cardoon (*Cynara cardunculus*), sesame (*Sesamum indicum*), marula (*Sclerocara birrea*), pumpkin (*Cucurbita pepo*), Jojoba (*Simmondsia chinensis*) (Moser, 2009).

Majority of this feedstock are found in Nigeria, being a tropical country, it has a wide variation of climate and soil condition (Akintayo, 2004) that can ease its cultivation. But inadequate information of the utilization and composition of the oil seeds indigenous to Nigeria is a major challenge (Akintayo, 2004). Beside vegetable oils, animal oil has been investigated for biodiesel production alongside with algae, microalgae, bacteria and fungi (Amin, 2009; Demirbas, 2009; Huang et al., 2010), wastes oils and fats (beef tallow, lard and yellow grease), hemp oil, waste cooking oil, grease by-product from omega-3-fatty acids production from fish oils have also been considered as feedstock for biodiesel production (Marchetti et al., 2008; Demirbas, 2003; Antczak et al., 2009). Other sources of biodiesel feedstock include animal fats are from varieties of domesticated animals such as cows, chickens, pigs as well as insects such as melon bug (*Aspongubus viduatus*), sorghum bug (*Agonoscelis pubescens*) (Moser, 2009). Waste oils include a variety of low-value materials such as used cooking or frying oils, vegetable oil soap stocks, acid oils. Waste oils are normally characterized by relatively high free fatty acid (FFA) and water contents and potentially the presence of various solid materials that must be removed by filtration prior to conversion to biodiesel. The chemical composition of biodiesel is dependent upon the feedstock from which it is produced, as vegetable oils and animal fats of differing origin have dissimilar fatty acid compositions (Moser, 2009).

Vegetable oils and biodiesel for transportation and automotive biofuel confers several advantages over fossil fuels because of its lower aromatic content, liquid nature, portability, low sulphur content, renewability and availability, whereas, high viscosity, flash and fire points, lower volatility and reactivity are the major shortcomings (Demirbas, 2003; Raja et al., 2011). A comparison of the physicochemical properties of fossil diesel, oil palm and oil palm based biodiesel is presented in Table 1.

Table 1: Some fuel property of diesel, biodiesel, palm oil

Property	**Diesel (Singh and Singh, 2010)**	**Biodiesel (Machacon et al., 2001)**	**Palm oil (Singh and Singh, 2010)**
Flash point ºC	76	-	267
Kinematic viscosity at 38ºC	3.06	4.3 – 4.5	39.6
Density kg/l	0.8550	0.872 – 0.877	0.9180
Cetane number ºC	50	64.3 – 70	42.0
Lower calorific/heating value (MJ/kg)	43.8	32.4	-
Carbon residue wt.%	-	-	0.23

The high viscosity of straight-chain vegetable oil as compared to diesel promotes unfavorable pumping causing inefficiency in mixing of fuel with air which results in incomplete combustion. It also reduces fuel atomization and increase fuel spray penetration. High flash point leads to formation of carbon deposits and inferior coking (Raja et al., 2011). Due to low volatility, the oil does not burn completely. This problem can be improved by transesterification reaction (Atadashi et al., 2011). These processes lower the viscosity and enhance other physicochemical properties of the oil (Ferella et al., 2010). Oil palm has high kinematic viscosity and low cetane number. Palm oil produces carbon residues as deposits during combustion.

Biodiesel is alternative fuel for diesel engines produced from renewable source with relatively low heating value (Table 1). Biodiesel is a non-toxic biodegradable fuel (Ogaboh et al., 2010), that is mainly produced from vegetable oil and animal fats, which comprise of triglycerides (TG), diglycerides (DG) and monoglycerides (MG) (Wenzel et al., 2006). Biodiesel has attracted considerable interest as an alternative fuel for combustion in compression–ignition (diesel) engines (Moser, 2009). The commonly used method for biodiesel production is transesterification. The resulting products contain alkyl ester product, unreacted starting material, residual alcohol and catalysts (Knothe, 2006). The byproducts is glycerol which is separated from the biodiesel (Knothe, 2006), and further purified.

Biodiesel has become more attractive recently because of its environmental advantages and the fact that it is made from renewable resources. There are lots of challenges in the biodiesel production including availability of feedstock as well as its composition. The technologies for feedstock conversion itself as well as the function of the biodiesel also have some drawbacks.

Besides this, it has environment benefits as well as economic benefits including Job creation, provision of modern energy carriers especially in the rural communities, and thereby reducing urban migration and CO_2 reduction in the atmosphere (Demirbas, 2009). Benefits of biofuels include energy security, environmental protection.

Notwithstanding, the benefits of biodiesel and despite Nigeria being the fifth largest producer of oil palm, the country has not commenced commercial production of biodiesel from palm based feedstock. This paper therefore focused on the science of biodiesel production and the challenges of biodiesel production in Nigeria from oil palm and concludes by suggesting ways of boosting the biodiesel sector in Nigeria.

Science of Biodiesel Production

Biodiesel is mostly produced through esterification and transesterification reactions. The esterification of triglyceride is with the aim of reducing the FFA of the feedstock. Transesterification results to fatty acid methyl ester (FAME) production and subsequently purification. In the transesterification process alkalis and enzymes are both used independently. Both approaches have their strengths and limitations (Table 2).These processes are discussed in the following subsections;

Table 2: comparison of different approaches employed in biodiesel production

Reaction conditions	Alkalis	Enzymatic
Temperature	60 – 70 C	30 – 40
FFA in triglycerols	Saponification	Methyl ester
Methyl ester yield	Normal	High
Separation	Difficult	Easy
Purification	Repeated washing	None
Production cost	Cheap	Expensive
Water in raw material	Interfere with the reaction	No interference

Source Shah et al., 2003; Helwani et al., 2009

Esterification

Esterification involves the reaction of alcohol, acid and TG to form ester and glycerol. In the production of biodiesel, it is a pretreatment process. Pretreatment is necessary to reduce soap formation during the reaction and ease the extensive handling for separation of biodiesel and glycerol together with removal of catalyst and alkaline wastewater (Meher et al., 2006). Two methods of pretreatment are acid-alkaline and enzymatic using lipase.

Acid-Alkaline Pretreatment

A common approach to reduce the FFA content of a feedstock when it exceeds 1.0 wt.% (Mbaraka et al., 2003; Zhang et al., 2003; Wang et al., 2005) is a two-step process in which acid pretreatment of the feedstock to lower its FFA content is followed by transesterification with homogenous base catalysts to produce biodiesel. In a typical acid pretreatment procedure, FFA are esterified to the corresponding FAME in the presence of heat, excess methanol, and acid catalyst, usually sulfuric acid, hydrochloric acid (Ghaly et al., 2010; Nebel and Mittelbach, 2006; Kumartiwari et al., 2007; Meng et al., 2008). The two-step procedure readily accommodates high FFA-containing low-cost feedstocks for the preparation of biodiesel (Canakci and Van Gerpen 1999, 2001). Other potential strategies for the production of biodiesel from feedstocks with high FFA content include feedstock purification such as refining, bleaching, and deodorization to remove FFA content and other undesirable materials (Zappi et al., 2003).

Lipase Pretreatment

Lipases constitute a various and abundant family of enzymes which are produced by animals, plants and microorganisms. Of these, microbes have been found to produce high yields of lipases compared to the animal and plants (Ghaly et al., 2010). Because their bulk production is easy, the commercialization of microbial lipases and their involvement in biodiesel production are common compared to that from plants and animals (Akohet al., 2007). Ester, oil, or tert-butanol appears to be a way to improve the apparent performance of the pretreatment of immobilized lipases, making them more economically attractive for industrial biodiesel production. Immobilization of lipase is the attachment of the enzyme onto a solid support or the confinement of the enzyme in a region of space (Jegannathan et al., 2008). Enzymes do not form soaps and can esterify both FFA and TG in one step without the need for subsequent washing step (Fjerbaek et al., 2009). Thus enzymes have an interesting prospect for industrial-scale production for reduction of production costs. This is especially the case when using feeds high in FFA, especially second-generation raw materials like spent oils, animal fat and similar waste fractions, with high FFA and water content and large variation in raw material quality (Fjerbaek et al., 2009).

The pretreatment works by intruding the immobilization of enzymes through the enhancement of mass transfer by surface layer or intra-particle phase as well as shielding the enzyme vicinity from inhibiting alcohols and glycerol (Fjerbaek et al., 2009). Lipases hydrolyze TG (Saliset al., 2005) and are capable of catalyzing other unnatural reactions. They act on the ester bonds of carboxylic acids allowing them to carry out their primary reaction of hydrolyzing fats (Joseph et al., 2008).This involves the soaking of enzyme in a medium prior to use in the transesterification reaction (Ghaly et al., 2010). This pretreatment helps to minimize the deactivation of the enzyme which is most commonly due to the use of lower chained alcohols (Ranganathan et al., 2008). However, pretreatment mediums such as isopropanol, methyl oleate, tert-butanol have been employed for transesterification reaction (Fjerbaeket al., 2009). The impact of a pretreatment may show significant effect in batch reactors, but probably has no considerable effect on long time use in continuous reactors. In this case, regeneration is done either by using a solvent such as tert-butanol or regenerating the enzymes by other means. Pretreatment and regeneration seem to be essential aspects in achieving high productivities in enzymatic biodiesel production.

Transesterification

Transesterification is the exchange of the alcohol moiety of an ester with another alcohol moiety (Ghaly et al., 2010; Ranganathan *et al*., 2008) (Fig. 1). Transesterification has been shown to be the simplest and most efficient route for biodiesel production in commercial quantities, against less eco-friendly, costly and eventual low yield methods of pyrolysis and microemulsification. Hence, transesterification has emerged as the most popular method for biodiesel production (Ma and Hanna, 1999; Akoh*et al*., 2007). There are at least three methods of transesterification; acid, alkaline and enzymatic with the use of lipase.

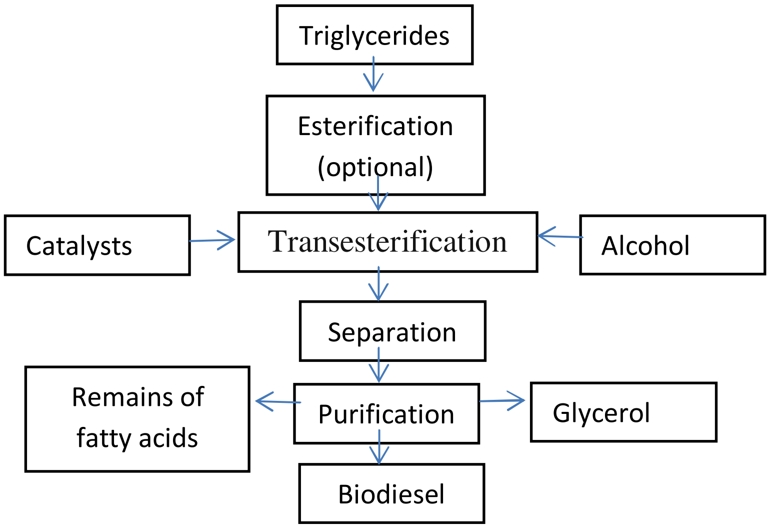

Fig 1: Processes of transesterification (Pierre, 2008)

Alkalis Transesterification

Transesterification reaction involves a TG reaction with a short-chain monohydric alcohol normally in the presence of a catalyst at elevated temperature to form FAME and glycerol (Banerjee and Chakraborty, 2009; Moser, 2009; Zabeti et al., 2009; Al-Widyan and Al-Shyoukh, 2002). The conversion of TG to biodiesel is a stepwise process whereby the alcohol initially reacts with TG as the alkoxide anion to produce FAME and DG, which reacts further with alcohol (alkoxide) to liberate another molecule of FAME and generate MG. Lastly, MG undergoes alcoholysis to yield glycerol and FAME, with the combined FAME collectively known as biodiesel

Typically, three moles of biodiesel and one mole of glycerol are produced for every mole of TG that undergoes complete conversion. Transesterification depends on several major variables including catalyst type, alcohol type, catalyst-oil -oil ratio, alcohol –to-oil ratio, reaction temperature, time and rate of agitation, FFA and water content of the feedstock (Ma and Hanna, 1999). The transesterification reaction is reversible, although the reverse reaction is negligible, because glycerol is not miscible with FAME, especially when using methanol as the alcohol component (Moser, 2009). Methanol is the most popular alcohol used in transesterification process because it is relatively cheap compared to other alcohols. When methanol is used in the process, the reaction is known as methanolysis.

A wide range of catalysts may be used for biodiesel production, such as homogenous and heterogeneous acids and bases, sugars, lipases and other heterogeneous materials. In general, acids are more appropriate for feedstocks' with high FFA content. Homogenously catalyzed reactions generally require less alcohol, shorter reaction times, and more complicated purification procedures than heterogeneously catalyzed transesterification reactions. Heterogeneous lipases are generally not tolerant of methanol, so production of ethyl or higher esters is more common with enzymatic method (Akor et al., 1983). The homogeneous catalysts include alkalis and acids (Vicente et al., 2004) while the lipase are the heterogeneous catalysts. The most commonly used alkali catalysts are sodium hydroxide, sodium methoxide and potassium hydroxide (Vicente et al., 2004).

Acidic Transesterification

Acidic transesterification has been shown to be tolerant of free fatty acids (Liu, 1994; Aksoy et al., 1988). The reaction of acidic transesterification of vegetable oil MG is presented in Fig. 2. Nonetheless, it can be used in both DG and TG (Singh and Singh, 2010). The protonation of carbonyl group of the ester leads to the carbonation, and nucleophilic attack of the alcohol produces a tetrahedral intermediary product (Singh and Singh, 2010), which eradicates glycerol to form a new ester and to regenerate the catalyst. Hence, acid is used when water and FFA of the triglycerides are high. Despite the high yield and no soap formations during acid pretreatment, the corrosive nature of acid, slow reaction rate and higher temperature conditions limit the use of the technology for esterification reactions (Freedman *et al*., 1984; Bacovsky *et al*., 2007). In the enzymatic tranesterification approach, selection of alcohol, use of solvents, lipase pretreatments, alcohol to oil molar ratio, water activity/content of the system, reaction temperature among others factors affects the yield of biodiesel production (Ghaly et al., 2010).

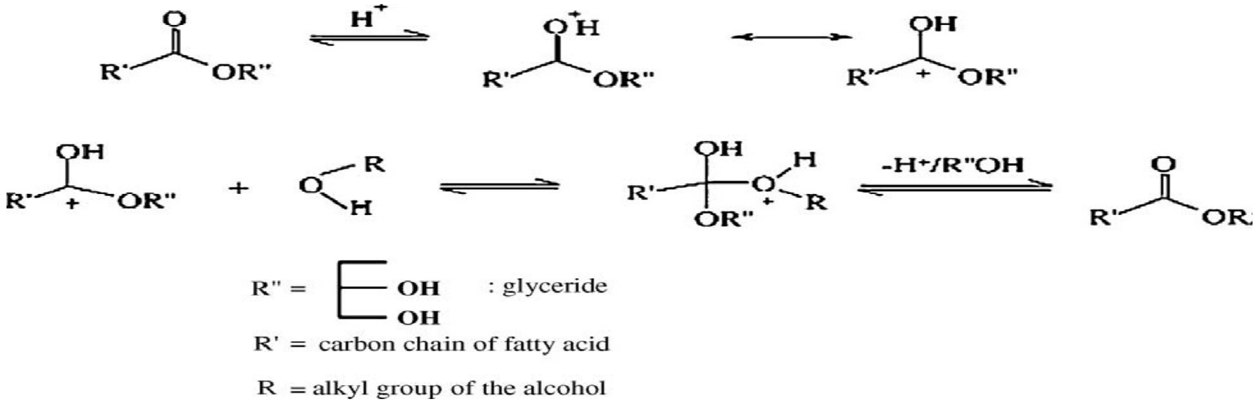

Fig 2: Acidic transesterification pathway (Singh and Singh, 2010)

Lipase Transesterification

In enzymatic transesterification lipases are used for biodiesel production from TG. Lipases from bacteria and fungi are the most commonly used for transesterification, and optimal parameters for the use of a specific lipase depend on the origin as well as the formulation of the lipase. In general, the best enzymes are able to reach conversions above 90%, while reaction temperatures vary between 30 and 50ºC (Ghaly et al., 2010). This lipase is able to convert tri-, di and monoglycerides into FAME while catalyzing the esterification of FFA. A wide range of lipases has been used for enzymatic transesterification and esterification. Gupta *et al*. (2004) reported thirty- eight separate bacterial sources from which common lipase are derived. These microbes that have been recommended for biodiesel production which includes *Aspergillus niger*, *Bacillus thermoleovorans*, *Burkholderia cepacia*, *Candida antarctica*, *Candida cylindracea*, *Candida rugosa*, *Chromobacterium viscosum*, *Fusarium heterosporum*, *Fusarium oxysporum*, *Getrichum candidum, Humicola lanuginose*, *Oosporalactis*, *Penicillium cyclopium*, *Penicillium roqueforti*, *Pseudomonas aeruginosa*, *Pseudomonas cepacia*, *Pseudomonas fluorescens*, *Pseudomonas putida*, *Rhizomucor* *miehei*, *Rhizopus arrhizus*, *Rhizopus chinensis, Rhizopus circinans*, *Rhizopus delemr*, *Rhizopus fusiformis*, *Rhizopus japonicas* NR400, *Rhizopus oryzae*, *Rhizopus stolonifer* NRRL1478, *Rhodotorula rubra*, *Saccharomyces cerevisiae*, *Staphylococcus hyicus*, *Thermomyces lanuginose* (Akohet al., 2007; Fjerbaeket al., 2009). In all these microbes, *Candida antarctica*, *Candida rugosa*, *Pseudomonas cepacia*, *Pseudomonas fluorescens*, *Rhizomucor miehei*, *Rhizopus chinensis*, *Rhizopus oryzae* and *Thermomyces lanuginose* have produced the most effective lipases for transesterification (Vasudevan and Briggs, 2008). However, *Candida Antarctica* displayed high activity in methanolysis and ethanolysis but showed a lower conversion yield for other alcohols. Other aspects of lipase transesterification are low product inhibition with high FAME yield, low reaction time, and possible reuse of the enzyme, temperature and alcohol resistance and ease of lipase production (Ghaly et al., 2010). The typical process by which lipases are used to produce FAME are presented in Fig. 3. The benefits of using lipases in biodiesel production includes ability to work in different media such as biphasic or monophasic systems, they are robust and versatile, and can be produced in large quantities, downstream separation is relatively easy, immobilization enhances the reuse of enzymes, high thermostability and short-chain alcohol-tolerant (Bacovsky*et al.*, 2007; Robles –Medina *et al.*, 2009).

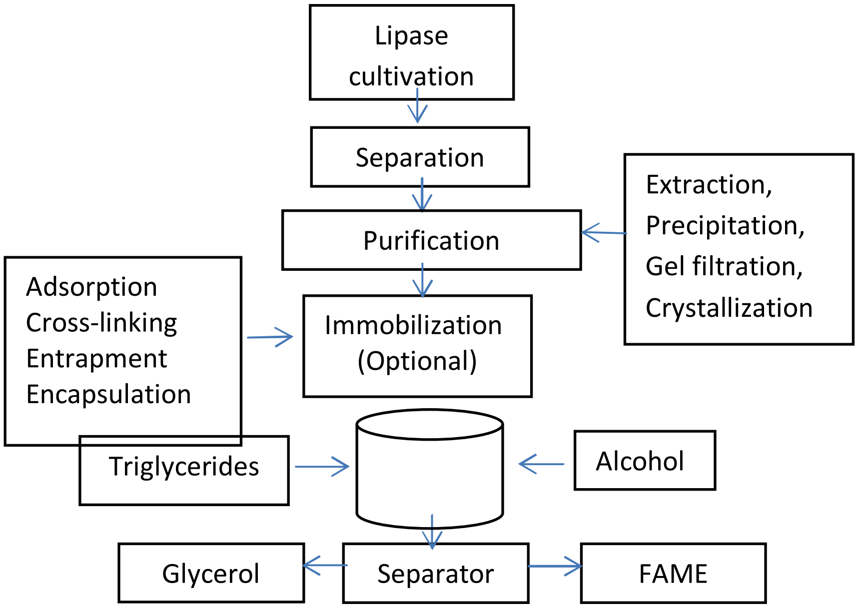

Fig 3: Enzymatic production of FAME (Du et al., 2008)

Purification

The acid and alkali Transesterification processes are energy intensive (Xu and Wu, 2003). The post treatments are required at the end of transesterification reaction producing mixture of esters, glycerol, MG and DGs, pigments, unreacted alcohol, catalyst and tri, di and monoglycerides. These post treatment involves separation of glycerol by gravitational settling, neutralization of the catalyst, deodorization and pigments removal (Antczaket al., 2009) depending on the approach used for biodiesel production.

The Challenges Of Biodiesel Production In Nigeria

Nigeria is the largest producer of oil palm in Africa and the fifth largest in the world. In 2007, the country released the Nigerian Biofuel Policy and Incentives (NNPC, 2007; Ohimain, 2010). Since then, the country has made little progress (Ohimain, 2012a) towards the actualization of the policy especially biodiesel production, principally due to shortage of feedstock, poor quality of oil palm processed by smallholders, technological challenge and poor policy framework.

Feedstock Supply Challenges

The palm oil that Nigeria has selected as a feedstock for biodiesel production could be a major challenge when the production commences fully. Oil palm is a major staple in Nigeria and its use for biodiesel production could trigger food versus fuel conflicts. Palm oil prices are high in Nigeria and other countries such as Malaysia and Indonesia are considering exporting palm oil to Nigeria (Nnorom, 2012). The situation of edible feedstock in Nigeria may be worrisome as food insecurity has become a critical element of Nigeria's poverty profile (Oshewolo, 2011). Palm oil is a multipurpose raw material used by both food and non-food industries for the manufacturing of margarine, soap, candle, base for lipstick, waxes and polish bases, confectionaries.

Nigeria is one of the food-deficit countries in sub-Saharan Africa (Davies, 2009) and is rank among the hungriest people of the world (Oshewolo, 2012). With likely increase in the prices of staple food items like corn up to 180 per cent by 2030 (corn is another biofuel crop). Nigeria is likely to be the hardest hit with 70 per cent of its population poor and spending more than 80 per cent of their income on food (Akpochafo, 2011). From this, focusing on green fuel production now using vital food crops may deteriorate the poverty state in Nigeria (Oshewolo, 2012).

The yields of Nigeria oil palm are relatively low compared to other oil palm producing countries like Malaysia, Thailand and Indonesia (Table 3). This is because 80% of oil palm plantations in Nigeria are wild groves (Ohimain et al., 2012c). The drawbacks of biodiesel include constraints on the availability of agricultural feedstock.

Table 3: Crude palm oil yield produced from different oil palm producing countries

Yield %	Countries	References
9.4 – 12.8	Nigeria	Ohimain et al., 2012c
23.5	Indonesia	Hambali et al., 2010
25 – 28	Thailand	Prasertsan and Prasertsan, 1996
23.52	Indonesia/Malaysia	Mahlia et al., 2001

The main problem for current biodiesel production is high cost. According to the statistics, 70% of manufacturing cost of biodiesel is from feedstock. Biodiesel fuels prepared from feedstock that meet at least majority of the ASTM and EU criteria will hold the most promise as alternatives to petro-diesel. In general, there are four major biodiesel feedstock categories: algae, oilseeds, animal fats, and various low-value materials such as used cooking oils, greases, and soap stocks (Moser, 2009). Traditional oilseed feedstock for biodiesel production predominately includes soybean, rapeseed/canola, palm, corn, sunflower, cottonseed, peanut, and coconut oil. Nigeria is an agrarian economy, with enormous oil palm. Currently Nigeria is ranked fifth in the world with 850 metric tonnes of palm oil over the past three years and forecast for the next two years are shown that the Nigerian oil palm sector is stagnated unlike Malaysia, Indonesia, Thailand and Columbia (Table 4). However, petroleum provides over 90 percent of Nigeria's foreign exchange earnings, even though the petroleum industry of the economy contributes 30% to the gross domestic product in comparison to 40 percent from agriculture (Oniemola and Sanusi, 2009).

Table 4: Palm oil; world supply, distribution and forecast

Production	**2008/09**	**2009/10**	**2010/11**	**2011/12**	**Oct 2012/13**	**Nov 2012/13**
Indonesia	20500	22000	23600	25900	27000	28000
Malaysia	17259	17763	18211	18202	18500	18500
Thailand	1540	1345	1288	1546	1700	1700
Colombia	795	770	750	915	960	960
Nigeria	850	850	850	850	850	850
Other	3074	3145	3224	3286	3317	3317
Total	44018	45873	47923	50699	52327	53327

Source: USDA, 2012

Processing Challenges

The Nigeria oil palm sector is dominated by smallholder processors producing oil palm of low quality for biodiesel production because of high FFA, water content and impurities (Ohimain et al., 2012a). Authors have variously reported high values of FFA for palm oil in Nigeria including 7.04 – 12.24% (Aletor et al., 1990), 2.67 – 4.20% (Okechalu et al., 2011), 2.6 – 2.9% (Onwuka and Akaerue, 2006), 6.39% (Ngando et al., 2011), 8.44 – 10.30% Ohimain et al., 2012a). The high FFA is associated with the processing procedure. This is a major challenge because over 80% of palm oil mill are processed by smallholders who typically make use of manual and /or traditional techniques for processing (Ohimain et al., 2012a; Ohimain et al., 2012b), which basically increases the FFA of the palm oil. Storage also increases the FFA content of palm oil. Besides, palm oil produced by smallholders in Nigeria often solidifies even at ambient tropical climatic conditions.

Feedstock quality in large part dictates what type of catalyst or process is needed to produce FAME that satisfies relevant biodiesel fuel standards such as ASTM D6751 or EN 14214 (Moser, 2009). If the feedstock contains a significant percentage of FFA (>3 wt.%), typical homogenous base catalysts such as sodium or potassium hydroxide or methoxide will not be effective as a result of an unwanted side reaction in which the catalyst will react with FFA to form soap (sodium salt of fatty acid) and water (or methanol in the case of sodium methoxide), thus irreversibly quenching the catalyst and resulting in an undesirable mixture of FFA, unreacted TAG, soap, DAG, MAG, biodiesel, glycerol, water, and/or methanol (Lotero et al., 2005). The base-catalyzed transesterification reaction will be significantly retarded if the FFA content of the feedstock is 3 wt.% or greater (Canakci and Van Gerpen1999, 2001). FFA in oils and fats can pose a great problem during transesterification. The basic catalysts such as sodium or potassium hydroxides are the most common, since the process is faster and the reaction conditions are moderated (Freedman et al., 1984). However, their utilization in vegetable oil transesterification produces soaps by neutralizing the FFA in the oil (Atadashi *et al*., 2011). The saponified product formed tends to be strengthened at ambient temperatures and the reaction mixture may gel and form a semi-solid substance that is very difficult to recover (Vicente et al., 2004). Soap formations are undesirable side reactions, because they partially consume the catalyst, decrease the biodiesel yield and complicate the separation and purification steps (Atadashi *et al*., 2011; Vicente et al., 2004). For example, virtually quantitative yields of biodiesel are obtained with homogenous base catalysts in cases where the FFA content of the feedstock is 0.5 wt.% or less (Naik et al., 2008). A further complicating factor of high FFA content is the production of water upon reaction with homogenous base catalysts. Water is particularly problematic because, in the presence of any remaining catalyst, it can participate in hydrolysis with biodiesel to produce additional FFA and methanol. This has a significant impact on the transesterification reaction (Leung and Guo, 2006). Refining can be used to increase the quality of palm oil via the reduction of FFA, water and impurities. However, feedstock refining further increases production costs as a result of the additional equipment, time, and manpower that are required.

Technological Challenges

Despite the benefits of renewable alternative fuel, biodiesel usage presents a number of technical problems that must be resolved before it will be more attractive as blend stock and/or alternative to petro-diesel. Such problems include low temperature properties, degradation during storage, high kinematic viscosity, low volumetric density, air emissions containing high levels of NOx and the need for addition infrastructure for blending and distribution. Efforts are required to enhance the low-temperature properties of biodiesel and maintaining biodiesel quality against degradation during long-term storage. Sustaining fuel quality for a long time is a serious concern for biodiesel producers, dealers, and users. The cost-effective techniques for enhancing oxidative stability of biodiesel are treatment with antioxidant additives. The use of additives to improve fuel performance is well known in the energy sector. Storage tanks for biodiesel require frequent cleaning before filling them with biodiesel. Monitoring the storage conditions of the tanks for temperature, moisture content, exposure to direct sunlight, and the atmosphere is required. Because biodiesel stored over long periods should be monitored regularly for signs of degradation. In this regard, it is recommended that biodiesel should not be stored for longer than 6 months.

High kinematic viscosity disturbs fuel atomization during injection and hence needs modified fuel injection systems. It produces relatively high NOx levels during combustion, due to the high oxygen content (Moser, 2009; DeOliveira et al. 2006). The volumetric energy density is quite low; it can cause dilution of engine lubricant oil, requiring more frequent oil change than in standard diesel-fueled engines. A modified refuelling infrastructure is needed to handle biodiesels, which adds to their total cost (Singh and Singh, 2010). These technological challenges have not been addressed in Nigeria.

Policy Challenges

In compliance to the August 2005 government directive on biofuel, the country released the Nigerian Biofuel Policy and incentives in 2007 (NNPC, 2007; Ohimain, 2010), which mandated the Nigerian National Petroleum Corporation (NNPC) to receive and blend 20% of biodiesel into the petro-diesel fuel sold in Nigeria (B20). The policy created an immediate demand of 480 million litres of biodiesel per year, which could increase to 900 million litres in 2020. The policy mandated the NNPC to purchase all biodiesel produced in Nigeria. The aim of the policy is to link the agricultural sector with the petroleum sector, in order to boost the agricultural and rural sectors. Incentives included in the policy for emerging biofuel companies include waivers (VAT, withholding and import duty), loans and insurance coverage (Ohimain, 2010). Recent studies have shown that the policy is insufficient to transform the country into a biofuel economy (Ohimain, 2012; Oshewolo, 2012). Nigeria therefore needs additional policies for the biofuel sector to succeed.

CONCLUSION AND THE WAY FORWARD

The primary market for biodiesel in the near to long-term future is probably to be as a blend stock in petro-diesel. As such, it is critical that a thorough understanding of biodiesel development from various feedstocks and fuel properties of the resultant biodiesel, such as exhaust emissions, low temperature operability, oxidative stability, water content, kinematic viscosity, lubricity, and corrosiveness is attain. Nigeria has chosen palm oil for biodiesel production. The country currently produces substantial quantity of palm oil for food consumption alone. The use of palm oil as biodiesel feedstock needs to be critically evaluated and balanced with other competing food uses of the oil. We suggest the use of inedible oil sources such as palm press fibre oil, rubber oil, raffia palm oil etc for biodiesel production.

Enzymatic transesterification is an attractive method for biodiesel production over chemical methods because of the reduced feedstock limitations. Although, this approach has been extensively reported, unfortunately it has not gained attention in commercial scale in most countries (Ghaly et al., 2010). The use of enzyme catalysts eliminates the problems associated with acid and alkali catalysts as well as presents other production advantages. Enzymes do not form soaps: hence there is no restriction on free fatty acid content (Harding *et al*., 2007; Fjerbaek *et al*., 2009). Unlike the acid catalysts, enzymes are not severely inhibited by water, so there is little concern about water content (Dizge and Keskinler, 2008). Enzymes are capable of totally converting FFA to FAMEs. Low cost feedstock such as waste oils and lard can be considered for biodiesel production using lipases (Fukuda *et al*., 2001). Enzymes are often immobilized when used, this enhances separation of products, producing high quality glycerol and subsequently allowing the reuse of the catalyst (Akoh*et al*., 2007). In view of the poor quality of oil palm processed in Nigeria, the country should consider the enzymatic approach in the production of biodiesel. These enzymes are expensive, but Nigeria is blessed with abundant substrate such as oil palm processing wastes upon which these lipase producing microbes can grow.

REFERENCES

Akintayo ET (2004). Characteristics and composition of *Parkiabioglobbossa*and *Jatrophacurcas*oils and cakes. Bioresource Technology. 92: 307-310.

Akoh CC, Chang S, Lee G and Shaw J (2007). Enzymatic approach to biodiesel production. J. Agric. Food Chem. 55: 8995 – 9005.

Akor AJ, Chanallor WJ and Raubach N (1983). The potential of palm oil as motor fuel.Transactions of the American Society of Agricultural Engineers, pp. 23-28.

Akpochafo P (2011). *Resolving Food Crisis in Nigeria*. http://nigerianpilot.com/?q=content/resolving-food-crisis-nigeria. Accessed December 12, 2012.

Aksoy HA, Kahraman I, Karaosmanoglu F and Civelekoglu H (1988). Evaluation of Turkish sulphur olive oil as an alternative diesel fuel. JAOCS 65 (6): 936–938.

Alamu OJ, Waheed MA and Jekayinfa SO (2007). Alkali-catalysed Laboratory Production and Testing of Biodiesel Fuel from Nigerian Palm Kernel Oil. Agricultural Engineering International. 9:1-11.

Aletor VA, Ikhena GA and Egharevba V (1990). The quality of some locally processed Nigerian palm oil: An estimation of some critical variables. Food Chemistry. 36: 311-317.

Al-Widyan MJ and Al-Shyoukh AO (2002). Experimental evaluation of the transesterification of waste palm oil into biodiesel. Bioresource Technology. 85: 253 – 256.

Amin S (2009). Review of biofuel oil and gas production processes from microalgae. Energy conservation and Management. 50(7): 1834 – 1840.
Antczak MS, Kubiak A, Antczak T and Bielecki S (2009). Enzymatic biodiesel synthesis-key factors affecting efficiency of the process. Renew. Energy 34:1185-1194.
Aransiola EF, Daramola MO and Ojumu TV (2012). Nigeria *Jatrophacurcas*oil seeds: prospects for biodiesel production in Nigeria. International Journal of Renewable Energy Research. 2(2): 317 – 325.
Atadashi IM, Aroua MK and Aziz AA (2011). Biodiesel separation and purification: a review. Renewable Energy. 36: 437 – 443.
Bacovsky D, Korbitz W, Mittelbach M and Worgetter M (2007). Biodiesel Production: Technologies and European Providers. IEA, Task 39 Report T39-B6, Graz, Austria, p: 104.
Banerjee A and Chakraborty R (2009). Paramteric sensitivity in transesterification of waste cooking oil for biodiesel production-a review. Resources, Conservation and Recycling. 53: 490 – 497.
Berchmans HJ and Hirata S (2008). Biodiesel production from crude *Jatrophacurcas* L. seed oil with a high content of free fatty acids. Bioresource Technology. 99: 1716 – 1721.
Canakci M and Van Gerpen J (1999). Biodiesel production via acid catalysis. Trans. ASAE 42: 1203–1210.
Canakci M and Van Gerpen J (2001). Biodiesel production from oils and fats with high free fatty acids. Trans. ASAE 44: 1429–1436.
Davies AE (2009). 'Food Security Initiatives in Nigeria: Prospects and Challenges. Journal of Sustainable Development in Africa. 11(9): 186-202.
Demirbas A (2006). Global biofuel strategies. Energy Educ. Sci. Technol. 17:27–63.
Demirbas A (2007). Importance of biodiesel as transportation fuel. Energy Policy. 35:4661–4670.
Demirbas A (2003). Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey. Energy conservation and management. 44(13): 2093 – 2109.
Demirbas A (2009). Production of biodiesel from algae oils. Energy sources Part A: Recovery, Utilization, and Environmental Effects. 31(2): 163 – 168.
DeOliveira E, Quirino RL, Suarez PAZ and Prado AGS (2006). Heats of combustion of biofuels obtained by pyrolysis and by transesterification and of biofuel/diesel blends. Thermochim. Acta. 450: 87–90.
Dizge N and Keskinler B (2008). Enzymatic production of biodiesel from canola oil using immobilized lipase. Biomass Bioenergy. 32: 1274-1278.
Du W, Li W, Sun T, Chen X and Liu D (2008). Perspectives for biotechnological production of biodiesel and impacts. Applied Microbiol. Biotechnol. 79: 331-337.
Ferella F, Mazziotti G, De Michelis I, Stanisci V and Veglio F (2010). Optimization of the tranesterification reaction in biodiesel production. Fuel 89: 36 – 42.
Fjerbaek L, Christensen KV and Norddahl B (2009).A review of the current state of biodiesel production using enzymatic transesterification. Biotechnology and Bioengineering. 102(5): 1298 – 1315.
Freedman B, Pryde EH and Mounts TL (1984). Variables affecting the yields of fatty esters from transesterified vegetable oils. J. Am. Oil Chem. Soc. 61(10):1638–1643.
Fukuda H, Kondo A and Noda H (2001). Biodiesel fuel production by transesterification of oils. J. Biosci. Bioeng. 92: 405-416.
Ghaly AE, Dave D, Brooks MS and Budge S (2010). Production of Biodiesel by Enzymatic Transesterification: Review. American Journal of Biochemistry and Biotechnology. 6 (2): 54-76.
Gupta R, Gupta N and Rathi P (2004). Bacterial lipases: An overview of production, purification and biochemical properties. Applied Microbiol. Biotechnol. 64: 763-781.
Hambali E, Thahar A and Komarudin A (2010). The potential oil palm and rice biomass as bioenergy feedstock. 7th Biomass Asia Workshop, November 29 – December 01, 2010, Jakarta, Indonesia.
Harding CC, Chang S, Lee G and Shaw J (2007). Enzymatic approach to biodiesel production. J. Agric. Food Chem. 55: 8995-9005.
Hasibuan S, Ma'ruf A and Sahirman (2009). Biodiesel from low grade used frying oil using esterification transesterification process. MakaraSains 13(2): 105-110.
Helwani US Jr, Othman MR, Aziz MR, Fernando WJN and Kim J (2009). Technologies for production of biodiesel focusing on green catalytic techniques: a review. Fuel Processing Technology. 90: 1502 – 1514.
Huang G, Chen F, Wei D, Zhang X and Chen G (2010). Biodiesel production by microalgal biotechnology. Applied Energy. 87(1): 38 – 46.
Jegannathan KR, Abang S, Poncelet D, Chan ES and Ravindra P (2008). Production of biodiesel using immobilized lipase-A critical review. Crit. Rev. Biotechnol. 28: 253-264.

Joseph B, Ramteke PW and Thomas G (2008). Cold active microbial lipases: Some hot issues and recent developments. Biotechnol. Advan. 26: 457-470.

Knothe G (2006). Analyzing biodiesel: standards and other methods. JAOCS 82(10): 823 – 833.

Kumartiwari AK, Kumar A and Raheman H (2007). Biodiesel production from Jatropha oil (*Jatrophacurcas*) with high free fatty acids: An optimized process. Biomass Bioenergy. 31: 569–575.

Leung DYC and Guo Y (2006). Transesterification of neat and used frying oil: optimization for biodiesel production. Fuel Process. Technol. 87: 883-890.

Liu K (1994). Preparation of fatty acid methyl esters for gas chromatographic analysis of lipids in biological material. JAOCS 71(11):1179–87.

Lotero E, Liu Y, Lopez DE, Suwannakarn K, Bruce DA and Goodwin JG Jr (2005). Synthesis of biodiesel via acid catalysis. Ind. Eng. Chem. Res. 44: 5353–5363.

Ma F and Hanna MA (1999). Biodiesel production: A review. Bioresour. Technol. 70: 1-15.

Machacon HTC, Shiga S, Karasawa, T and Nakamura H (2001). Performance and emission characteristics of a diesel engine fueled with coconut oil-diesel fuel blend. Biomass Bioenergy. 20:63–69.

Mahlia TMI, Abdulmium MZ, Alamsyah TMI and Mukhlishien D (2001). An alternative energy source from palm wastes industry for Malaysia and Indonesia. Energy Conversion and Management. 42: 2109 - 2118.

Marchetti JM, Miguel VU and Errazu AF (2008). Techno-economic study of different alternatives for biodiesel production. Fuel Process. Technol. 89: 740-748.

Mbaraka IK, Radu DR, Lin VSY and Shanks BH (2005). Organosulfonic acid-functionalized mesoporoussilicas for the esterification of fatty acid. J. Catal. 219: 329–336.

Meher LC, Sagar DV and Naik SN (2006). Technical aspects of biodiesel production by tranesterification-a review. Renewable and Sustainable Energy Review. 10: 248 – 268.

Meng X, Chen G and Wang Y (2008). Biodiesel production from waste cooking oil via alkali catalyst and its engine test. Fuel Process Technol. 89: 851–857.

Moser BR (2009). Biodiesel production, properties, and feedstocks. In Vitro Cell. Dev. Biol. – Plant 45:229–266.

Naik M, Meher LC, Naik SN and Das LM (2008). Production of biodiesel from high free fatty acid Karanja (Pongamiapinnata) oil. Biomass. Bioenergy 32: 354–357.

Nebel BA and Mittelbach M (2006). Biodiesel from extracted fat out of meat and bone meal. Eur. J. Lipid Sci. Technol. 108: 398–403.

Ngando EGF, Mpondo MEA, Dikotto EEL and Koona P (2011). Assessment of the quality of crude palm oil from smallholders in Cameroon. Journal of Stored Products and Postharvest Research. 2(3): 52-58.

Nnorom N (2012). Plantation Owners Forum of Nigeria (POFON) raises alarm over removal of tariff on imported palm oil. Vanguard Wednesday 05 September 2012. Pp. 36.

Ogaboh AAM, Ushie ME, Abam FI, Agba MS and Okoro J (2010). Developing the Biofuel Industry for Effective Rural Transformation in Nigeria. European Journal of Scientific Research. 40(3): 441-449.

Ohimain EI (2010). Emerging bio-ethanol projects in Nigeria: Their opportunities and challenges. Energy Policy. 38: 7161-7168.

Ohimain, E. I., 2012a. Can the Nigerian biofuel policy and incentives (2007) transform Nigeria into a biofuel economy? Energy Policy. In press

Ohimain EI (2012b). The benefits and potential impacts of household cooking fuel substitution with bio-ethanol produced from cassava feedstock in Nigeria. Energy for Sustainable Development. 16: 352 – 362.

Ohimain EI, Daokoru-Olukole C, Izah SC and Alaka EE (2012a). Assessment of the quality of crude palm oil produced by smallholder processors in Rivers State, Nigeria. Nigerian Journal of Agriculture, Food and Environment. 8(2): 28 - 34.

Ohimain EI, Oyedeji AA and Izah SC (2012b). Employment effects of smallholder oil palm processing plants in Elele, Rivers State, Nigeria. International Journal of Applied Research and Technology. 1(6): 83 - 93.

Ohimain EI, Izah SC and Obieze FAU (2012c). Material-mass balance of smallholder oil palm processing in the Niger Delta, Nigeria. Advances Journal of Food Science and Technology. In press.

Okechalu JN, Dashen MM, Lar PM, Okechalu B and Gushop T (2011). Microbiological quality and chemical characteristics of palm oil sold within Jos Metropolis, Plateau State, Nigeria. Journal of Microbiology and Biotechnology Research 1(2): 107-112.

Oniemola PK and Sanusi G (2009). The Nigerian bio-fuel policy and incentives (2007): A need to follow the Brazilian pathway. International Association for Energy Economics. Fourth Quarter 2009. Pp 35 39.

Onwuka GI and Akaerue BI (2006). Evaluation of the Quality of Palm Oil Produced by different methods of processing. Research Journal of Biological Sciences. 1: 16-19.

Oshewolo S (2011). 'Poverty Reduction and the Attainment of the MDGs in Nigeria: Problems and Prospects'. *Africana: A Journal of Ideas on Africa and the African Diaspora*. 5(2): 211-238.

Oshewolo S (2012). Designed to fail? Nigeria's quest for biofuel. Afro Asian Journal of Social Sciences. 3(3): 1 – 15.

Pierre CK (2008). Development of a biodiesel industry in Rwanda: Processing and fuel quality control. Proceeding of the Workshop on biodiesel production and marketing, Kigali, Rwanda.

Prasertsan S and Prasertsan P (1996). Biomass residues from palm oil mill in Thailand: an overview on quantity and potential usage. Biomass Bioenergy. 11(5):387-395.

Raja SA, Smart DSR and Lee CLR (2011). Biodiesel production from Jatropha oil and it characterization. Research Journal of Chemical Sciences. 1(1): 81 – 87.

Ranganathan SV, Narasimhan SL and Muthukumar K (2008). An overview of enzymatic production of biodiesel. Bioresour. Technol. 99: 3975-3981.

Ribeiro A, Casro F and Carvaiho J (2011). Influence of free fatty acid content in biodiesel production on non –edible oils, Wastes: Solutions, Treatments and Opportunities. 1st International Conference, 12th – 14th September, 2011.

Robles-Medina A, Gonzalez-Moreno PA, Esteban –Cerdán L and Molina-Grima E (2009). Biocatalysis: Towards evergreener biodiesel production. Biotechnol. Adv. 27: 398-408.

Salis A, Pinna M, Monduzzi M and SolinasV (2005). Biodiesel production from triolein and short chain alcohols through biocatalysis. J. Biotechnol. 119: 291-299.

Shah S, Sharma S and Gupta MN (2003). Enzymatic tranesterification for biodiesel production. Indian Journal of Biochemistry and Biophysics. 40: 392 – 399.

Singh SP and Singh D (2010). Biodiesel production through the use of different sources and characterization of oils and their esters as the substitute of diesel: a review. 14: 200 – 216.

United State Department of Agriculture (USDA) (2012). World Agricultural production. Foreign agriculture series WAP 11-12. Published 11 September 2012.

Vasudevan PT and Briggs M (2008). Biodiesel production-current state of the art and challenges. J. Indus. Microbiol. Biotechnol. 35: 421-430.

Vicente G, Martınez M and Aracil J (2004). Integrated biodiesel production: a comparison of different homogeneous catalysts systems. Bioresource Technology 92 (2004). 297–305.

Wang PS, Tat ME and Van Gerpen J (2005). The production of fatty acid isopropyl esters and their use as a diesel engine fuel. J. Am. Oil Chem. Soc. 82: 845–849.

Wenzel B, Tait M, Módenes A and Kroumov A (2006). Modelling chemical kinetics of soybean oil transesterification process for biodiesel production: an analysis of molar ratio between alcohol and soybean oil temperature changes on the process conversion rate. Bioautomation 5: 13 – 22.

Xu G and Wu GY (2003). The investigation of blending properties of biodiesel and no. 0 diesel fuel. J. Jiangsu Polytechnique Univ. 15: 16-18.

Zabeti M, Daud WM and Aroua MK (2009). Activity of solid catalysts for biodiesel production: a review. Fuel Processing Technology. 90: 770 – 777.

Zappi M, Hernandez R, Sparks D, Horne J, Brough M, Arora SM and Motsenbocker WD (2003). A review of the engineering aspects of the biodiesel industry. Mississippi Biomass Council, Jackson, MS: 71 pp.

Zhang Y, Dube MA, McLean DD and Kates M (2003). Biodiesel production from waste cooking oil via two-step catalyzed process. Energy Convers. Manage. 48: 184–188.