

Development and Evaluation of Palm Kernel Oil Biodiesel Fuel

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ABSTRACT

This work considers the use of palm kernel oil (PKO) for the production of alternative renewable and environmental friendly diesel fuel (biodiesel). Laboratory scale quantities of PKO biodiesel were produced through transesterification reaction using 100g PKO, 20.0% ethanol (wt% PKO), 1.0% potassium hydroxide (KOH) catalyst at 60 C reaction temperature and 90 min. reaction time. The experiment was replicated three times and average results evaluated. The biodiesel produced was characterized as alternative diesel fuel through series of ASTM standard fuel tests. The transesterification process yielded 95.4% PKO biodiesel. The PKO biodiesel had 85.06% reduction of viscosity over its raw vegetable oil at 40 C. Higher specific gravity, pour point, and cloud point were obtained compared to that of commercial grade petroleum diesel (D2). Specific gravity values compare favorably with results for other vegetable oil biodiesel. Generally, results obtained were within limits set by various International Standards for biodiesel.

(Keywords: energy, environment, ethanol, palm kernel oil, biodiesel, renewable fuel)

INTRODUCTION

Growing concerns have been recorded for alternatives to conventional petroleum-based fuels (Al Widyand and Al Shyouk, 2002; Bernado *et al.*, 2003, Gupta *et al.*, 2006). This is due to the global consensus that the conventional sources of energy are finite in nature (Sambo, 1981; Agbo and Oparaku, 2006). From a recent report (Alamu, 2007; Alamu *et al.*, 2007c), available statistical data ranked Nigeria as one of the 20 largest oil producers in the world with a whopping 36 billion barrels of proven oil reserves at the beginning of year 2007 (EIA, 2007). In addition to its oil wealth, Nigeria has an estimated 182 trillion cubic feet (tcf) of proven natural gas reserves, the seventh largest reserves in the world (EIA, 2007). This amazing oil wealth notwithstanding, the Energy

Commission of Nigeria (ECN) recently expressed fears over future depletion of this non-renewable resource (ECN, 2005).

At present, ten major oil fields from the 20 largest world oil producers are already experiencing a decline in oil reserves (Alamu *et al.*, 2007c). From available records (Table 1), a total of 29 major world oil producing countries are already experiencing declining oil reserves from year 2005 to date. Since the instability in the Middle East, international oil prices have been on the increase, global petroleum markets have become volatile, and world crude oil supplies have become grossly characterized by instability (Chitra *et al.*, 2005; Gupta *et al.*, 2007). From a recent report, it is projected that the world oil prices will decline from \$68 per barrel in 2006 to \$49 per barrel in 2014. It is further projected to rise to \$59 per barrel in 2030 (EIA, 2007). These fluctuations in the world oil price pose a serious threat to the nation's economic and energy security; hence the urgent need to seek alternatives.

Additionally, petroleum-based energy sources pose severe threats to the environment from hazardous emissions (Munack *et al.*, 2000; Agbo and Oparaku, 2006). Industrial and economic development through conventional energy technologies have brought about significant environmental degradation and climate change with severe impact on human and aquatic life. Water, air, and soil have suffered serious damage from oil spills, especially in the Niger Delta – Nigeria's center for crude oil extraction.

As previously reported (Alamu *et al.* 2007a), severe environmental impacts have been ignored in the country's haste to develop the oil industry. This has generated militancy from the local (Ijaw) people making successful oil prospecting a nearly impossible task for the multinational companies in Nigeria.

Table 1: World Oil Producers with Declining Oil Reserves

Country	Oil (billion barrels)	
	Year-end 2005	January 1, 2007
Mexico	13.670	12.352
United States	29.922	21.757
Ecuador	5.060	4.517
Peru	1.097	0.930
Trinidad and Tobago	0.809	0.728
Italy	0.731	0.600
Norway	9.691	7.849
United Kingdom	3.998	3.875
Kazakhstan	39.620	30.000
Russia	74.436	60.000
Iran	137.490	136.270
Oman	5.572	5.500
Saudi Arabia	264.211	262.300
Syria	3.000	2.500
Angola	9.035	8.000
Congo (Brazzaville)	1.784	1.600
Egypt	3.720	3.700
Equatorial Guinea	1.765	1.100
Gabon	2.205	2.000
Sudan	6.405	5.000
Tunisia	0.681	0.400
Australia	4.045	1.592
Brunei	1.120	1.100
China	16.038	16.000
India	5.919	5.625
Indonesia	4.301	4.300
Malaysia	4.200	3.000
Thailand	0.527	0.290
Vietnam	3.119	0.600

Source: EIA,2007.

Environmental benefits offered by biodiesel in comparison to petroleum-based fuels include reduced exhaust emissions, improved biodegradability, reduced toxicity, and higher cetane rating which can improve performance and clean up emissions. Typical biodiesel produces about 65% less net carbon monoxide, 78% less carbon dioxide, 90% less sulphur dioxide, and

50% less unburnt hydrocarbon emission (Margaroni, 1998; Knothe and Steidley, 2005).

Nigeria is endowed with significant renewable energy resources including large and small hydroelectric power resources, solar energy, biomass, wind, potentials for hydrogen utilization, and development of geothermal and ocean energy (ECN, 2005; Alamu *et al.*, 2007). Within the biomass class, palm kernel oil (PKO) is one vegetable oil in Nigeria, which had hitherto suffered underutilization as edible oil. Available records (Table 2) (USDA, 1998) indicate Nigeria as one of the world producers of palm kernel from which PKO is derived.

It has been reported that in diesel engines, crude plant oils (such as PKO) can be used as fuel, either straight or as blend with petroleum diesel. However, use of neat vegetable oils are characterized by injector choking, engine deposits, and thickening of lubricants during extended operation of the engine. This has been attributed to the high viscosity of vegetable oils (Ryan *et al.*, 1982; Gupta *et al.*, 2007). The use of transesterified vegetable oils as fuel has been yielding successful results besides being a domestic, renewable resource that provides environmental benefits with lower emissions.

Several researchers (Verma *et al.*, 1998, Krahl *et al.*, 2005, and Gupta, 1994) have used bio-diesel as alternate fuel in the existing compression ignition (CI) engines without any modification. Promising results have been obtained by running CI engines on vegetable oil based bio-diesels. Soybean (US), rapeseed (Europe), oil palm (South-East Asia), and canola. These have been successfully used as renewable vegetable oil sources to generate biodiesel (Peterson *et al.*, 1990; Nouredini and Zhu, 1997; Yunus *et al.*, 2003).

Limited studies were, however, found in the literature on the use of PKO for biodiesel. Abigor *et al.* (2000) produced biodiesel from palm kernel oil by transesterification of the oil with different alcohols using PS30 lipase catalyst. This work reports production of PKO biodiesel via transesterification of the PKO with ethanol using alkali-catalyst, KOH, while the PKO biodiesel produced is characterized as alternative diesel fuel through ASTM standard tests for basic fuel properties.

Table 2: Nigeria's Share in the World Production of Palm-Kernel

Producing Country	Share of world total (million metric ton) production of palm-kernel					
	(1995/96)	(%)	(1996/97)	(%)	(1997/98)	(%)
World	4.978	100.000	4.306	100.000	5.379	100.000
Malaysia	2.483	49.879	2.629	61.054	2.570	47.778
Indonesia	1.410	28.325	1.590	36.925	1.700	31.604
Nigeria	0.270	5.424	0.260	6.038	0.250	4.648
Cote d'ivoire	0.064	1.286	0.059	1.370	0.063	1.171
Colombia	0.074	1.487	0.075	1.742	0.076	1.413
Thailand	0.080	1.607	0.092	2.137	0.105	1.952
Zaire	0.030	0.603	0.030	0.697	0.030	0.558
Equador	0.036	0.723	0.040	0.929	0.040	0.744
Others	0.525	10.546	0.531	12.332	0.545	10.132

Source: USDA, (1998)

MATERIALS AND METHODS

Transesterification Process and Materials

By the stoichiometry of the process, one mol of PKO is required to react with three moles of ethanol to produce three moles of the biodiesel and one mole of glycerol (Kavitha, 2003; Alamu *et al.*, 2007c). It is required that reaction temperature must be below the boiling point of alcohol used (Van Gerpen, 2004). Reaction time for biodiesel production ranges from less than 30 min. to more than two hours (Chitra *et al.*, 2005), while most researchers have used 0.1 to 1.2 % concentration of catalyst (wt% oil) (Alacantara *et al.*, 2000; Ma *et al.*, 1999; Chitra *et al.*, 2005; Gupta *et al.*, 2007).

Nigerian locally produced palm kernel oil was purchased at the local market in Ogiyo, Ogun State, Nigeria. 100g PKO was used for the transesterification process. The ethanol used (99% pure) is an analytical grade with boiling point of 78°C; while the KOH used was also an analytical grade product of Aldrich Chemicals, England. The blender used was a Dry and Wet mill Blender with a clear glass (1,250cc capacity) containers and stainless steel cutting blades. Other major materials used include scales, translucent white plastic container with bung and

screw-on cap, funnels, PET bottles and thermometer.

Experimental Procedures

20.0g of ethanol was measured and poured into a plastic container after which 0.5g of KOH was carefully added to the plastic container. The bung and the screw on the cap were replaced tightly. The container was swirled round thoroughly for about two minutes repeatedly about six times for complete dissolution of KOH in the ethanol to form potassium ethoxide. 100.0g of PKO was measured out, pre-heated to 60 C in a beaker, and poured into the blender. The prepared potassium ethoxide from the plastic container was carefully poured into the PKO. Then the blender lid was secured tightly and the blender switched on and agitation in the blender was maintained for 90 minutes. The mixture was poured from the blender into a PET bottle for settling and the lid was secured. The reaction mixture was allowed to stand overnight while phase separation occurred by gravity settling into clear, golden / pale liquid biodiesel on the top with the light brown glycerol at the bottom of the bottle. The PKO biodiesel was carefully decanted into a PET bottle leaving the glycerol at the base. The biodiesel was washed with water as detailed in Alamu (2007).

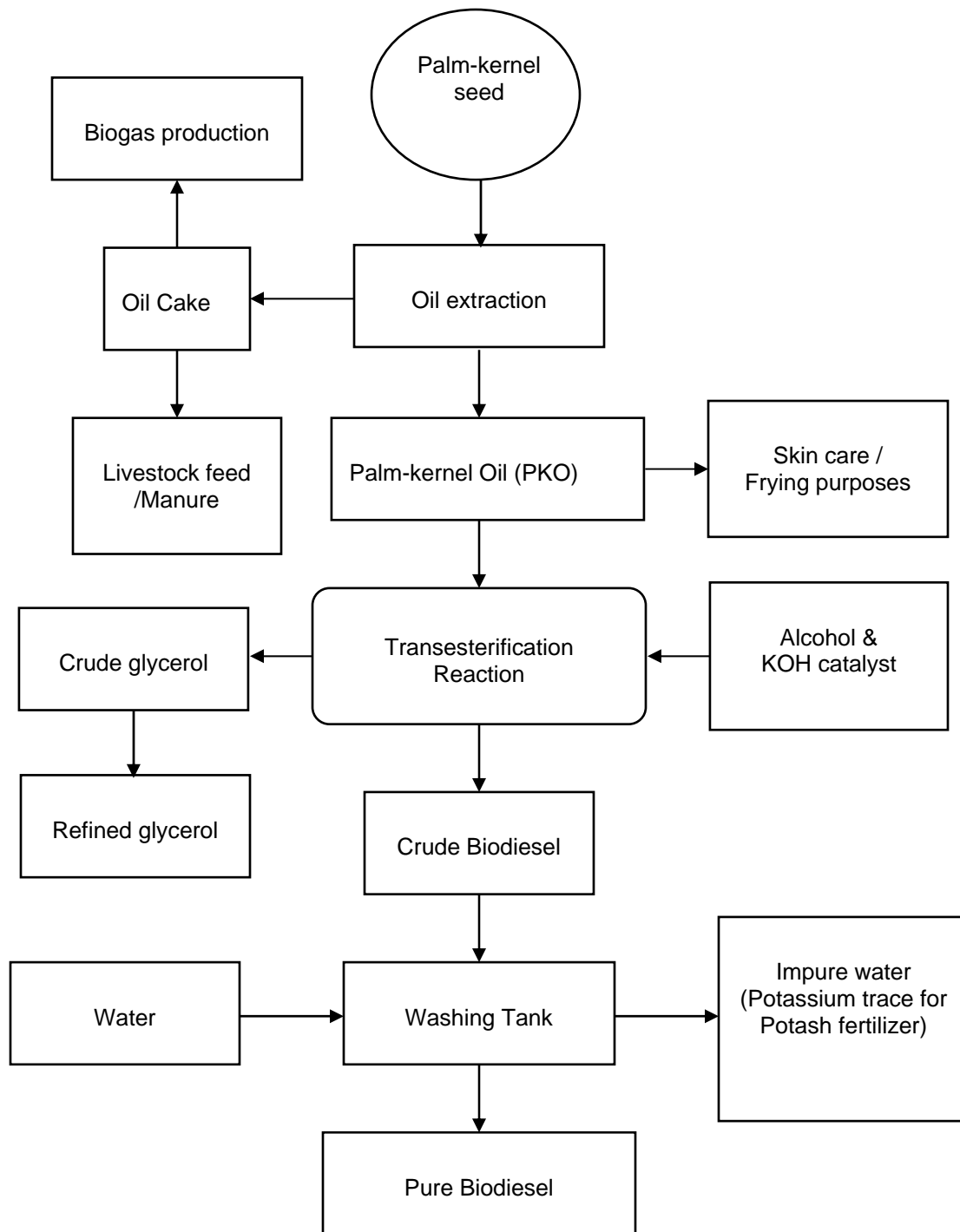


Figure.1: Process Flow Chart for Biodiesel Production from Palm-Kernel Oil

The procedure was replicated three times and average biodiesel yield as well as glycerol yield was measured.

Characterization of the biodiesel as fuel

ASTM standard fuel tests were subsequently carried out on the PKO biodiesel and Low sulphur diesel fuel (No.2 Diesel) purchased at a fuel station in Ifo, Nigeria.

Specific gravity and viscosity measurements were made using the Thermal-Hydrometer apparatus and Viscometer (Canon-Fenske Calibrated, 15cSt max. range), following ASTM standards D1298 and D445 respectively. The biodiesel was analyzed for cloud point and pour point using Baskeyl Setapoint cloud and pour point apparatus following ASTM standards D25100-8 and D97 respectively. Procedures for these tests have been reported (Alamu, 2007).

RESULTS AND DISCUSSION

Transesterification Experiment

The transesterification process yielded 95.4g PKO biodiesel and 23.2 glycerol, while 2.4g of the total reacting masses could not be accounted for. These losses have been attributed to some unreacted alcohol, residual catalyst, and emulsion removed during the washing stage of the production process (Alamu *et al.*, 2007a).

The results stated are averages of three different experimental runs. Detailed results for each of the experimental runs are as presented in Table 3.

Fuel Characterization

The PKO biodiesel produced and the petroleum diesel, used as control, were analyzed for basic fuel properties. Results obtained are presented in Table 4.

With raw PKO having viscosity 32.40 mm²/s, the PKO biodiesel viscosity obtained showed 85.06% reduction, thus enhancing its fluidity in diesel engine. Higher specific gravity, pour point, and cloud point were obtained compared to that of petroleum diesel. Values obtained for other properties have been compared with previous results for biodiesel from rapeseed, canola, beef tallow, soybean, frying oil, and coconut oil (Peterson *et al.*, 1990; Abigor *et al.*, 2000; Graboski and McCormick 1998; Schwab *et al.*, 1987; Alamu *et al.*, 2007a).

These values have also been checked against various international standards for biodiesel including ASTM D6751 (US), EN 14214 (Europe) and BIS (India) (Knothe and Steidley, 2005; Chitra *et al.*, 2005). Comparison made revealed good agreement with previous results as detailed in Alamu *et al.* (2007a).

Table 3: Results for the Transesterification Experiment

Experimental Conditions	1st Run	2nd Run	3rd Run	Average
Reaction temperature (approximated) (°C)	60	60	60	60
Reaction time (min.)	90	90	90	90
Palm kernel oil (PKO) quantity (g)	100	100	100	100
Ethanol quantity (g)	20.00	20.00	20.00	20.00
KOH (catalyst) concentration* (g)	1.00	1.00	1.00	1.00
PKO biodiesel obtained (g)	95.10	95.20	95.90	95.40
Glycerol obtained (g)	23.50	23.20	22.90	23.20
Losses (g)	2.40	2.60	2.20	2.40
PKO biodiesel yield (%)	95.10	95.20	95.90	95.40

*by weight of 100g PKO

Table 4: Fuel Characterization Results for PKO Biodiesel and Petroleum Diesel Fuel

Fuel Characteristics (Properties / Parameters)	Values	
	(PKO biodiesel)	(Petroleum diesel)
Viscosity (@ 40 C), (mm ² /s)	4.839	2.847
Specific gravity (@ 60 F/60 F)	0.883	0.853
Pour point, (C)	2	-16
Cloud point (C)	6	-12
Flash Point (C)	167	74

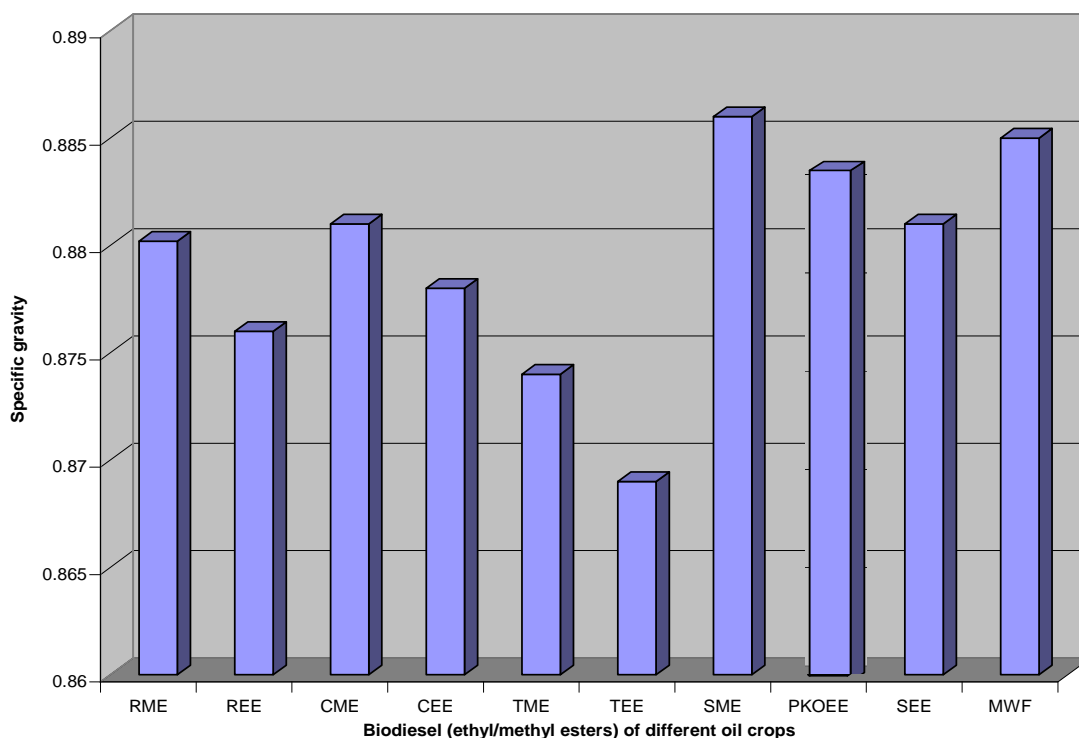


Figure 2: Comparison of Specific Gravity of PKO Biodiesel with other Biodiesel Fuel at 15.56 C.

A comparison of specific gravity of PKO biodiesel with selected biodiesel from other oil crops reveals closer property similarity with midwest biofuel methyl soyate, soybean ethyl ester, canola methyl ester, rapeseed methyl ester and canola ethyl ester; decreasing in that order, while beef tallow methyl ester is the most remotely similar in property with PKO biodiesel from the biofuels considered. This comparison is illustrated in Figure 2.

Comparison with Biodiesel Standards

At 15 C, the specific gravity obtained for the PKO biodiesel falls within the limit specified by various international standards. EN14214 (Europe),

ONC1191 (Austria), CSN656507 (Czech Republic), Journal Officiel (France), DINV51606 (Germany), UNI10635 (Italy) and SS155436 (Sweden) standards specify specific gravity ranges (0.86-0.9), (0.85-0.89), (0.87-0.89), (0.87-0.90), (0.875-0.9), (0.86-0.90), and (0.87-0.90) respectively for biodiesel fuel. From the results of this study, the specific gravity of 0.884 at 15 C obtained for the PKO biodiesel agrees with the above standards as its value falls within the recommended ranges.

CONCLUSIONS

From the development and evaluation of PKO biodiesel study, the following conclusions can be drawn:

- The transesterification process using 100g PKO, 20.0g ethanol, 1.0% KOH (by weight of PKO) at 60 C reaction temperature and 90 minutes reaction time yielded 95.4g PKO biodiesel.
- At 15.56 C, specific gravity of PKO biodiesel is 1.033958 times that of fossil diesel.
- At 40 C, the PKO biodiesel had 85.06% reduction of viscosity over its raw vegetable oil.
- Higher pour (2 C), cloud (6 C) and flash (167 C) points were obtained for the PKO biodiesel compared to -12 C, -16 C and 74 C respectively obtained for D2.

The limited fuel characterization carried out demonstrated that the PKO biodiesel produced can successfully fuel a diesel engine

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