

Synthesis and Evaluation of Biodiesel Fuel from Nigerian Palm Kernel Oil

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ABSTRACT

Despite the abundance of underutilized palm kernel oil in Nigeria, the lack of optimized, locally-adapted synthesis protocols and comprehensive performance evaluations for its conversion to biodiesel hinders the development of a sustainable, economically viable alternative to fossil diesel in the region. This study aims to synthesize and evaluate of biodiesel fuel from Nigerian palm kernel oil. Using petroleum diesel, higher pour points, cloud points, and specific gravities were found. The outcomes a sodium hydroxide (NaOH) catalyst, palm kernel oil was transesterified with ethanol to create palm kernel oil biodiesel. ASTM standard fuel tests were used to classify the generated gasoline as an alternate fuel for diesel engines. This study used 100g of palm kernel oil, 20.0% ethanol, 1.0% NaOH, a reaction temperature of 60°C, and 90 minutes for transesterification. 95.8% was obtained in reaction time. Three replications of biodiesel made from palm kernel oil. At 40 degrees Celsius, fuel tests on the biodiesel revealed an 85.06% decrease in viscosity compared to its raw palm kernel oil. In comparison to ordinary are consistent with those of other vegetable oil biodiesel. Thus, it is recommended that this feedstock be adopted for commercial biodiesel production in Nigeria using the optimized transesterification protocol.

1. INTRODUCTION

According to reports, contemporary biofuels are a viable long-term renewable energy source that has the ability to alleviate the security issues and environmental effects of the existing reliance on fossil fuels (Batidzirai *et al.*, 2006; Alamu *et al.*, 2025; Alamu, 2008; Gupta *et al.*, 2007). The usage of fossil fuels like coal, natural gas, and petroleum to supply human energy demands has been linked to environmental effects like global warming (Saravanan *et al.*, 2007; Munach *et al.*, 2001). Furthermore, there is a risk that the supply of these non-renewable energy sources will run out soon (Munach *et al.*, 2001; Sambo, 1981). According to numerous reports, the oil reserves of at least ten of the world's twenty biggest oil producers are already declining. According to published data, 29 of the world's largest oil-producing nations have already seen a decline in their oil reserves since 2005 (Alamu, 2008; EIA, 2007).

A low-carbon alternative to fossil fuels is biodiesel, including biofuel (Adewuyi, 2020). Biodiesel has lower exhaust emissions, better biodegradability, less toxicity, and a higher cetane rating than petroleum-based fuels, all of which can enhance performance and reduce emissions. About 65% less net carbon monoxide, 78% less carbon dioxide, 90% less sulfur dioxide, and 50% less unburned hydrocarbon emissions are produced by typical biodiesel (Ryan *et al.*, 1982; Krahl *et al.*, 2005; Olatunde *et al.*, 2021). Notably, additive effects, as slated in other studies including Akinyemi and Alamu, (2009); Adetunji *et al.* (2011); Oyelami

et al. (2023) and Babarinde *et al.* (2025) have documented their finding on biodiesel with positive outcomes (Alamu, 2008; Igwebuiké, 2023).

In recent years, the hunt for renewable energy sources has continued to garner interest. According to Odeyale *et al.* (2014), the transportation sector is one of the biggest fuel consumers. According to reports, vegetable oils can be blended with petroleum diesel or used directly as fuel in diesel engines (Gupta *et al.*, 2007; Math, 2007). However, these lubricants' high viscosity causes poor fuel atomization in CI engines, which leads to an incorrect fuel-air combination and ineffective combustion (Saravanan *et al.*, 2007; Bari *et al.*, 2002). Injector coking, engine deposits, and lubricant thickening during prolonged engine operation are other symptoms of the issue (Alamu, 2008; Ryan *et al.*, 1982; Igwebuiké, 2023). However, the transesterification process lowers the high viscosities of vegetable oils.

Significant findings about the successful transesterification of various vegetable oils from around the world to produce biodiesel have been documented in the literature. Rapeseed (Europe), soybeans (United States), oil palm (South-East Asia), rice bran oil, and jatropha curcus (India) are examples of such feedstocks. The current CI engines have also used unmodified biodiesel made from canola, leftover restaurant oil, and animal fats (Gupta *et al.*, 2007; Saravanan *et al.*, 2007; Krahl *et al.*, 2005; Al-Widyan and Al-Shyoukh, 2002; Chitra *et al.*, 2005).

One lauric vegetable oil that was previously underutilized as culinary oil in Nigeria is palm kernel oil (PKO). Nigeria is one of the world's top producers of palm kernels, according to the figures that are currently available. Nigeria contributed 0.27, 0.26, and 0.25 million metric tons to global palm kernel production during the 1995–1996, 1996–1997, and 1997–1998 production seasons, respectively. According to this record, Nigeria ranked higher than PKO-producing nations including Cote d'ivoire, Colombia, Thailand, Zaire, and Equador, and next to Malaysia and Indonesia (Alamu, 2008; Alamu *et al.*, 2009).

Abigor *et al.* (2000) used a PS30 lipase catalyst to transesterify palm kernel and coconut oils with various alcohols to create biodiesel. According to a few recent studies on the topic, the transesterification process employed a potassium hydroxide catalyst (Alamu, 2008; Alamu *et al.*, 2009; Alamu, 2007). However, there are limited investigations on the manufacturing and testing of biodiesel from Nigerian lauric oils in the literature. Thus, this study aimed to synthesis and evaluation of biodiesel fuel from Nigerian palm kernel oil. In addition, the PKO was trans-esterified with ethanol using an alkali catalyst (NaOH) to create biodiesel. ASTM standard tests for fundamental fuel characteristics such specific gravity, viscosity, pour point, and cloud point. The outcome of this study is anticipated to further define the PKO biodiesel generated as an alternative diesel fuel.

2. METHODOLOGY

According to stoichiometry, three moles of ethanol and one mole of PKO must react to make three moles of biodiesel and one mole of glycerol. Preliminary experiments and earlier research have yielded values for the various parameters employed as per the study of Alamu, (2008), Gupta *et al.* (2007), Chitra *et al.* (2005), Alamu, (2007), Alacantara *et al.* (2000), and Ma *et al.*, (1998). For this project, locally produced PKO was bought at the Onitsha Market, Nigeria. For the transesterification, 100g PKO was utilized. According to specifications, the NaOH used was also an analytical grade product from Aldrich Chemicals in England, and the ethanol used is 99% pure and has a boiling point of 78°C. The dry and wet mill blender that was utilized has stainless steel cutting blades and clear glass containers with a 1,250cc capacity. Scales, a translucent white plastic container with a bung and screw-on cover, funnels, thermometers, and PET bottles are other important materials.

2.1 Experimental Procedures

1.0 g of NaOH was carefully added to a plastic container after 20.0 g of ethanol was measured and poured into it in accordance with recognized protocols (Abigor *et al.*, 2000; Alamu, 2007). Both the bung and the cap screw were firmly put back in place. In order to completely dissolve the NaOH in the ethanol and create sodium ethoxide, the container was thoroughly swirled six times over the course of two minutes. The blender was filled with 100.0 g of PKO that had been metered out and heated to 60°C in a beaker. After carefully filling the PKO with sodium ethoxide from the plastic bottle and tightening the blender cover, the blender was turned on and left running for ninety minutes.

After pouring the slurry from the blender into a PET bottle to settle, the lid was securely fastened on. The reaction mixture was let to stand overnight while phase separation took place, with the light brown glycerol at the bottom of the bottle and the clear, pale, golden liquid biodiesel at the top due to gravity. Glycerol was left at the bottom of a PET bottle after the PKO biodiesel was gently decanted into it. As described earlier, water was used to wash the biodiesel (Alamu, 2007). The process was repeated three times, and the average yields of glycerol and biodiesel were recorded.

2.2 Characterization of the Biodiesel Fuel

PKO biodiesel and low-sulfur diesel fuel bought at a gasoline station in Ogbomoso, Nigeria, were subjected to standard fuel tests (ASTM). The Thermal-Hydrometer apparatus and viscometer were used to measure specific gravity and viscosity in accordance with ASTM standards D1298 and D445, respectively. Using Baskeyl Setapoint cloud and pour point equipment, the biodiesel was examined for cloud point and pour point in accordance with ASTM standards D25100-8 and D97, respectively. These tests' methods have been documented (Alamu, 2007).

3. RESULTS AND DISCUSSION

95.8 g PKO biodiesel and 22.4 g glycerol were produced by the transesterification process, with 2.8 g of the total reactive masses remaining unaccounted for. Some unreacted alcohol, leftover catalyst, and emulsion that were eliminated during the washing phase of the production process are attributed to these losses (Alamu, 2008; Alamu *et al.*, 2009). Three distinct experimental runs were averaged to produce the given results. Table 1 displays the specific findings for every experimental run. The cost per kilogram of biodiesel was determined to be lower than that of fossil diesel, indicating favorable economic outcomes. Additionally, renewable agricultural products are the main feedstocks (Alamu, 2007).

Table 1: Results for the Transesterification Experiment

Experimental Conditions	1 st Run	2 nd Run	3 rd 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
NaOH (catalyst) concentration* (g)	1.00	1.00	1.00	1.00
PKO biodiesel obtained (g)	96.20	95.30	95.90	95.80
Glycerol obtained (g)	22.40	22.60	22.20	22.40
Losses (g)	2.40	3.10	2.90	2.80
PKO Biodiesel yield (%)	96.20	95.30	95.90	95.80

*by weight of 100 g PKO

Basic fuel qualities were examined for both commercial-grade petroleum diesel and laboratory-scale PKO biodiesel. The results are shown in Table 2. As previously reported by Alamu (2008); Alamu (2007) and

Alamu *et al.* (2009), raw PKO had a viscosity of 32.40 mm²/s. in this study, the PKO biodiesel viscosity achieved demonstrated an 85.06% reduction. This will improve the fluidity of biodiesel in diesel engines. In comparison to petroleum diesel, higher specific gravity, pour point, and cloud point were attained. Figure 1 shows a comparison of the specific gravity of PKO biodiesel with specific biodiesel from various oil crops. For biodiesel made from rapeseed, canola, beef tallow, soybean, frying oil, and coconut oil as well as KOH-catalyzed PKO biodiesel, the values obtained for other properties compare favorably with earlier findings in the literature (Abigor *et al.*, 2000; Peterson *et al.*, 1990; Graboski and McCormick, 1998). These values have also been compared to other plant-oil-based biodiesel and a number of international biodiesel standards, such as ASTM D6751 (US), EN 14214 (Europe), and BIS (India). Table 2 for the EN 14214 standard, rapeseed ethyl ester, and canola ethyl ester biodiesel shows that the comparison showed good agreement.

Table 2: Fuel Characterization Results for PKO Biodiesel and Petroleum Diesel Fuel

Fuel Characteristics (Properties / Parameters)	PKO biodiesel	Petroleum diesel	EN14214 European Biodiesel Standard	Rapeseed* (Ethyl Ester) Biodiesel	Canola* (Ethyl Ester) Biodiesel
Viscosity (@ 40°C), (mm ² /s)	4.839	2.847	3.50-5.00	6.170	4.892
Specific gravity (@ 60°F/60°F)	0.883	0.853	0.86-0.90	0.876	0.878
Pour point, (°C)	2	-16	-	-2	-1
Cloud point (°C)	6	-12	-	-10	-6
Flash Point (°C)	167	74	>120	124	177

*Peterson *et al.* (1990)

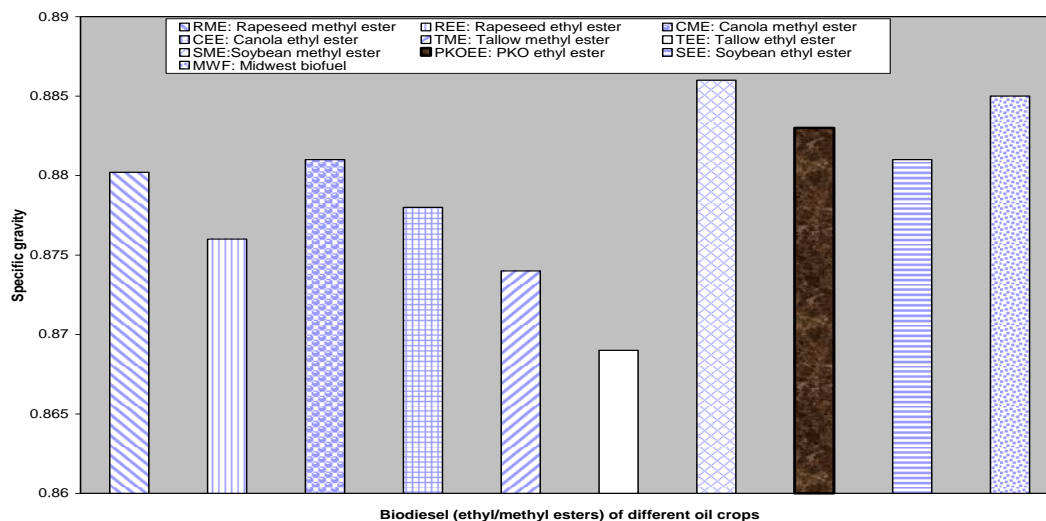


Figure 1: Comparison of specific gravity of PKO biodiesel with other biodiesel fuel at 15.56°C

The PKO biodiesel's specific gravity at 15°C is within the range given by several international biodiesel standards. For biodiesel fuel, 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) are specified by EN14214 (Europe), ONC1191 (Austria), CSN656507 (Czech Republic), Journal Officiel (France), UNI10635 (Italy), and SS155436 (Sweden). According to the study's findings, the PKO biodiesel's specific gravity of 0.884 at 15°C is in excellent compliance with the aforementioned biodiesel requirements.

4. CONCLUSION

The following conclusions can be made based on the fuel characterisation and production of PKO biodiesel: 95.8 g PKO biodiesel was produced by the transesterification method utilizing 100 g PKO, 20.0 g ethanol, and 1.0% NaOH (by weight of PKO) at 60°C reaction temperature and 90 minutes reaction time. PKO biodiesel has a specific gravity that is 1.033958 times higher than fossil diesel at 15.56°C. The viscosity of PKO biodiesel was 85.06% lower than that of its raw vegetable oil at 40°C. PKO biodiesel had higher pour (2°C), cloud (6°C), and flash (167°C) points than commercial grade fossil diesel fuel, which had -12°C, -16°C, and 74°C, respectively. The PKO biodiesel produced can run a diesel engine, according to the limited fuel characterisation that was done.

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