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PRODUCTION OF BIODIESEL FROM PALM KERNEL OIL USING FeO PROMOTED NaOH CATALYST THROUGH TRANSESTERIFICATION

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AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. Authors OSA, AN and MAO designed the study, wrote the protocol and interpreted the data. Authors OSA, KUO and MAO anchored the field study, gathered the initial data and performed preliminary data analysis. While authors OSA, KUO and OA managed the literature searches and produced the initial draft. All authors read and approved the final manuscript.

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ABSTRACT

Biodiesel was successfully produced using palm kernel oil through transesterification. The effect of FeO, NaOH and NaOH/FeO catalyst in were studied in the production of the biodiesel. From the results, NaOH catalyst is more suitable for higher yield of biodiesel than its mixture (NaOH/FeO) and the least yield of biodiesel was obtained from using FeO from Palm Kernel Oil. Optimum of biodiesel yield of 68.75% was obtained using 1 M of NaOH as the catalyst. The palm kernel oil had free fatty acid value 3.935 mgKOH/g, Saponification value 242 mgKOH/g, Iodine value of 23 g/100 and acid value 7.85 mgKOH/g. The Palm Kernel Oil base biodiesel had properties such as specific gravity 0.860, kinematic viscosity 3.3 mm^2/s, cetane number 45.5, cloud point 5 and acid value 0.5012 which agrees with biodiesel standard value.

Keywords: Biodiesel; catalyst; palm kernel oil; yield.

1. INTRODUCTION

Biodiesel also referred to as non-petroleum based fuel consists of short chain alkyl (methyl or ethyl) esters, made by transesterification of vegetable or animal fat (tallow), which can be used (blend conventional petrol diesel) in unmodified diesel engine vehicles [1]. According to [2], biodiesel production is through the chemical reaction of an animal fat or vegetable oil with an alcohol for instance methanol which requires the presence of a catalyst (usually a base) like potassium or sodium hydroxide which in turn produces new chemical compound called methyl esters. Biodiesel could be prepared from varieties of oil from vegetables like canola, corn, cotton seed oil, peanut, safflower, soybean, sun floweroil, palm oil, olive oil, palm kernel oil and coconut oil.

The most universally used alcohol in the preparation of biodiesel is methanol as a result of the following advantage it has, compared to other alcohol; it is cheap, it prevents the formation of soap, it does not produce azeotrope and reactivity is high, hence it is less difficult to recover [3]. Alcohol such as ethanol, butyl and iso-propanol can also be used.

Biodiesel can be considered to be a promising alternative to petroleum diesel and has attracted keen

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attention from many researchers all over the world [4]. The need to reduce global warming due to environmental pollution and the willingness of international community to curb greenhouse emission as stipulated in the Kyoto protocol in 1997 has encouraged the need to find more alternative to fossil fuels [5].The aim of this paper is production of biodiesel using crude palm kernel oil (PKO). Investigation of the influence of FeO, NaOH and NaOH/FeO catalyst on yield of biodiesel was carried out and will be shown as well as the characterization of the palm kernel oil and biodiesel produced.

2. METHODOLOGY

The major raw material that was used for this experiment is palm kernel oil (PKO). Chemicals used in this study were Petroleum ester (Burgoyne, 95%), Potassium hydroxide (Analar BDH, 95%), Phenolphthalein indicator, Glacial acetic acid (BDH Chemicals), Hydrochloric acid (Analar BDH, 36%), Potassium iodide (M&B, 95%), Sodium thiosulphate (95%), Methanol (BDH Chemicals, 99.9%), Sulphuric acid (AnalarBDH, 98%), Diethyl ester(Analar BDH, 95%),Toluene and Distilled water (Laboratory made).

Some equipment and materials used includes; Digital weighing balance (Citizen, MP300), Thermometer, Magnetic stirrer (Gallenkamp, SINT320.01N), Thermostat hot plate (Gallenkamp, HPL/600/050E), Oven (Gallenkamp), Viscometer (Gallenkamp), pHmeter (Rex, pHs25), Rotary evaporator (Techmei & Technic, TT107R), Flash point tester (Pensky martens tester, Seta), Water bulb (Daihan lab. Tech.), Pyrometer bottle (Pyrex, England), Separating funnel (Pyrex, England), Cloud & pour point bath (koelter), Density Bottle (Pyrex, England), Pycometer bottle (Pyrex, England), Measuring cylinder (Pyrex, England), Burette (Pyrex, England), Pipette (Pyrex, England), Round bottom flask (Pyrex, England), Beakers (Pyrex, England).

A two-step procedure catalysed esterification was employed followed by alkali catalysed transesterification.

2.1 Pre-treatment through Acid Esterification

The crude PKO containing water was heated at a temperature of about 120°C for 30minutes to dehydrate the oil [6]. The heated PKO was cooled and allowed to settle overnight. After cooling, the PKO was filtered to remove the solid particles from it and then esterified by agitating it with a mixture of 300 mL ethanol and 1% w/v of hydrochloric acid. The mixture was placed on a magnetic stirrer equipped with hot plate at 60°C with a constant agitation for 1 hour. The mixture was then allowed to settle in a separating funnel into the layer. The upper layer contains ethanol and water while the lower layer containing the palm kernel oil was carefully decanted. The ethanol was distilled to dry free it from water content. The free fatty acid is now determined and found to be less than 2% [7].

2.2 Alkaline Esterification

For the transesterification process, 60 mL of pre-treated PKO was measured into a conical flask and heated to a temperature at 60°C. Varying mass of 0.5 – 2.0 gof FeO was measured into a beaker containing 100 mL of ethanol and then stirred until the FeO catalyst dissolved completely. The resulting solution of ethanol was poured into the flask containing the oil for a reaction time 1 hour. The resulting solution was then stirred vigorously for 6 minutes using a magnetic stirrer at 120 rpm and the mixture was allowed to settle under gravity for 24 h. The mixture separates with two separate layers, the layer containing biodiesel, ethanol soap and residual catalyst and lower layer containing glycerol. The glycerol was gradually driven off. The pH of the biodiesel was measured and found to be acidic whereas phosphoric acid was added to neutralize the residual catalyst [7].

This procedure was repeated using NaOH/FeO and NaOHcatalyst. The quantity of biodiesel collected was measured, recorded and characterized.

2.3 Purification of the Ethyl Ester

50 mL of water was boiled to a temperature of about 50°C was used to washing the methyl ester phase. Washing was doneso asto remove the remaining unreacted ethanol and catalyst in the biodiesel. The warm water was poured into the separating funnel containing the biodiesel; left for about 5 minutes to settle and separation of soapy water was done. Washing was done continuously until the unreacted ethanol and catalyst were completely removed. The washed biodiesel was heated up of about 100°C to evaporate the water residue. The biodiesel was slowly heated up to 50°C and held here for a period of about 20 minutes to dry.

2.4 Characterization of the Biodiesel Produced

The produced biodiesel was characterized by determining: the specific gravity ASTM D1298 by hydrometer method, flash point ASTM D93 by Pensky-Martens close up meter, cloud point

(ASTM D2500), kinematic viscosity ASTM D445 – Kinematic viscosity, pour point ASTM D97, Cetane number, Acid number (ASTM D-664), Iodine value.

3. RESULTS AND DISCUSSION

3.1 Crude Palm Kernel Oil (PKO) Analysis

The palm kernel oil was characterized to determine the physical and chemical properties as these properties play a key part in the quantity and quality of the fuel produced (biodiesel).

From Table 1, it was observed that the experimental palm kernel oil properties were quite close to that reported in literature by [8]. According to [9], increasing acid value of the oil tends to gradually decrease the biodiesel yield. Hence, an acid value of 7.85 mgKOH/g will affect the yield of biodiesel produced.

The use of FeO catalyst in the production of biodiesel as shown in Table 2 reveals that more glycerine and less biodiesel were formed. Maximum volume of biodiesel was 30 mL which is 37.50% of the yield at a catalyst concentration of 1.0 w/v % was used.

From results obtained in Table 3, NaOH catalyst gave higherbiodiesel production using palm kernel oil. The least volume of glycerine was 20 mL and maximum volume of biodiesel obtained was 55 mL, 68.75% biodiesel yield at NaOH concentration of 1 w/v %.

A mixture of FeO/NaOH catalyst resulted in higher glycerine volume as shown in Table 4, when compared to using only NaOH catalyst for the production of biodiesel. The presence of FeO in the catalyst mixture could be used to explain why the glycerine volume increased and the biodiesel volume decreased.

Table 1. Summary of the properties of experimental crude palm kernel oil comparison with results from [8]

Properties	Experimental PKO	Literature PKO
Free fatty acid (mgKOH/g)	3.935	5.830
Saponification value (mgKOH/g)	242.00	232.81
Iodine value (g/100 g)	23.00	41.42
Acid value (mgKOH/g)	7.85	11.60
Peroxide value	2.48	1.70
Refractive index	1.334	1.453

Table 2. Production of biodiesel from PKO using FeO catalyst

Vol. of oil (mL)	Vol. of solvent (mL)	Catalyst conc. (w/v%)	Vol. of glycerine (mL)	Vol. of biodiesel (mL)	Biodiesel yield (%)
60	20	0.5	45	27	33.75
60	20	1.0	42	30	37.50
60	20	1.5	48	26	32.50
60	20	2.0	50	24	30.00

Table 3. Production of biodiesel from PKO using NaOH catalyst

Vol. of oil (mL)	Vol. of solvent (mL)	Catalyst conc. (w/v) %	Vol. of glycerine (mL)	Vol. of biodiesel (mL)	Biodiesel yield (%)
60	20	0.5	28	40	50.00
60	20	1.0	20	55	68.75
60	20	1.5	25	46	57.50
60	20	2.0	34	38	47.50

Table 4. Production of biodiesel from PKO using FeO/NaOH catalyst

Vol. of oil (mL)	Vol. of solvent (mL)	Catalyst conc. (w/v%)	Vol. of glycerine (mL)	Vol. of biodiesel (mL)	Biodiesel yield (%)
60	20	0.5	36	32	40.00
60	20	1.0	30	40	50.00
60	20	1.5	46	30	37.50
60	20	2.0	48	25	31.25

Table 5. Physico-chemical properties of biodiesel produced in comparison with ASTM standard

Properties	Experimental value	ASTM
Specific gravity (kg/m^3)	0.8600	0.8477
Kinematic viscosity (mm^2/sec)	3.3000	2.8470
Acid value (mgKOH/g)	0.5012	0.5000
Cetane number	45.50	46 to 52
Cloud point (°C)	5.0000	4.8 to 5.3
Flash point (°C)	116	752
Pour point (°C)	-11.0000	-10 to 0.001
Heat of combustion (BTU/gal)	130, 000	140,000

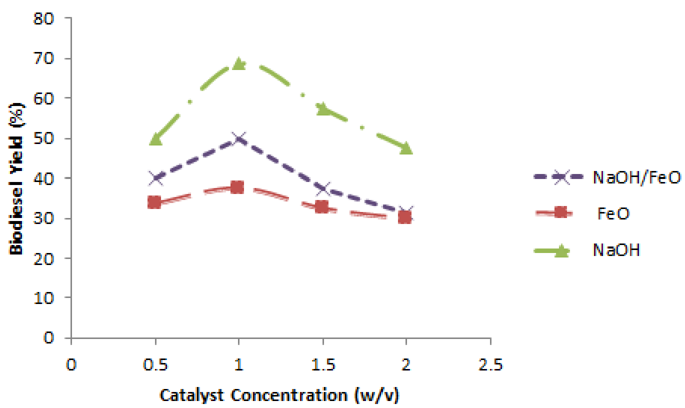

Fig. 1. Biodiesel yield for the various catalyst used against catalyst concentration

In this study, the catalyst concentration was varied from 0.5 to 2.0w/v %. The result as shown in Fig. 1, reveals that low catalyst concentration as 0.5 w/v % low yield of ethyl ester. 1 w/v % catalyst concentration yielded the maximum biodiesel volume while further increase of the catalyst to 1.5 w/v % and 2.0 w/v % produces steady decrease in yield of biodiesel. [9] reported 97% biodiesel yield using semi-refined rape seed oil with acidity of 0.55 mgKOH/g and heterogeneous catalyst (CaO). They observed that as acidity oil used increased, biodiesel yield decreased, hence, high acid value of oils results in catalyst loss as soap [9]. The catalyst concentration below 1 w/v % produce less yield because less triglycerides is converted to ethyl ester (biodiesel), while the decrease in biodiesel yield above 1.5 to 2.0 w/v % catalyst concentration irrespective of the type catalyst can be ascribable to the formation of soap which decrease the ethyl ester. Thus, this can be attributed to the fact that the neutralization of free fatty acid by the catalyst basic sites [10].

4. CONCLUSION

The present study was designed to ascertain the effect of catalyst (FeO, NaOH and FeO/ NaOH) in the production of biodiesel from Palm Kernel Oil. From the results, it was observed that NaOH catalyst is more suitable than its mixture (NaOH/FeO) and the least volume of biodiesel resulted from using FeO in the production of biodiesel from PKO.

Biodiesel yield was 68.75% using 1 w/v% of NaOH as the catalyst which is quite low when compared with 95.8% yield obtained by [11] from palm kernel oil using 1 w/v % NaOH catalyst at 60^{o}C and reaction time of 90 minutes. This low yield may be as a result of lower reaction time. It was observed that low catalyst concentration below 1 w/v % produced less yield because less triglyceride is converted to ethyl ester while the decline in yield has the catalyst concentration increases above 1.5 to 2.0 w/v % is due to the formation of soap which decreases the ethyl ester.

The Palm Kernel Oil base biodiesel result as alternative diesel fuel had properties such as specific gravity 0.860, kinematic viscosity 3.3 mm^2/s, cetane number 45.5, cloud point 5 and acid value 0.5012 are in good agreement with biodiesel standard value.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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