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INFLUENCE OF REACTION TIME IN THE PRODUCTION OF BIODIESEL FROM PALM OIL MILL EFFLUENT (POME)

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ABSTRACT

The reaction time affects the conversion efficiency of the trans-esterification process of converting oil to biodiesel. In this study, the effect of reaction time at different time interval on biodiesel yield was examined. Bio-oil was extracted from palm oil mill effluent (POME) using soxhlet extraction apparatus. The feed oil to solvent ratio used was 3:1. N-hexane reagent of 80 ml was added to 240 ml of feed oil collected from a local palm oil mill in Ogbomoso and heated for 60 minutes to a temperature of 75^{o}C. Biodiesel was produced from the trans-esterification reaction of 150 ml bio-oil with 0.046 g of potassium hydroxide as catalyst and 25 ml of ethanol which serves as the limiting reagent at a reaction temperature of 65^{o}C. The reaction time was varied over a range of 60, 90, 120 and 150 minutes. The results indicated that optimal reaction time was 120 minutes with maximum percentage yield of 80%. The properties of biodiesel produced in this study meet the specification of ASTM and EN standards. This study has therefore indicated the influence of reaction time to achieve highest production of biodiesel from POME.

KEYWORDS: Biodiesel, Ethyl ester, Reaction Time, Trans-esterification, POME.

INTRODUCTION

With crude oil prices soaring, vegetable oils are fast becoming the new sources of energy. Palm oil in comparison to other vegetable oils is a cheaper raw material for biodiesel production and is the most abundantly produced vegetable oil in the world (Ramachandran *et al*., 2005). Although palm oil is still mostly used in the manufacture of food products, it is now increasingly being used as a feedstock for biodiesel for automotive use and power generation (Panapanaan et al., 2009).

Modern biofuels have been reported as a promising long term renewable energy source which has potential to address both environmental impacts and security concerns posed by current dependence on fossil fuels Alamu *et al*., 2007 Batidzirai *et al*., 2006 Gupta *et al*., 2007. Fossil fuels such as petroleum, coal and natural gas, which have been used to meet the energy needs of man, are associated with negative environmental impacts such as global warming (Munac *et al*., 2001; Saravanan *et al*., 2007). Besides, supply of these non-renewable energy sources is threatening to run out in a foreseeable future (Munac *et al*., 2001; Sambo, 1981). It has been widely reported that not less than ten major oil fields from the 20 largest world oil producers are already experiencing decline in oil reserves. Recently published data also revealed a total of 29 major world oil producing countries already experiencing declining oil reserves from year 2005 to 2007 (EIA,2007; Alamu *et al*., 2007).

In comparison to petroleum-based fuels, bio-diesel offers 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 un-burnt hydrocarbon emission (Knothe and Steidley, 2005b; Krahl *et al*., 2005; Margaroni, 1998; Ryan *et al*., 1982). The search for renewable energy resources continues to attract attention in recent times. It has been reported that in diesel engines, vegetable oils can be used directly as fuel, or as blend with petroleum diesel (Gupta *et al*., 2007; Math, 2007). However, due to high viscosity of these oils, poor fuel atomization occurs in CI engines resulting in improper fuel-air mixture and inefficient combustion (Bari *et al*., 2002; Saravanan *et al*., 2007). The problem also manifests in injector coking, engine deposits and thickening of lubricants during extended operation of the engine (Alamu *et al*., 2007; Ryan *et al*., 1982). The high viscosities of vegetable oils are however reduced through the process of trans-esterification. Satisfactory results have appeared in the literature on production of biodiesel through trans-esterification

of different kinds of vegetable oil from different parts of the world. Such feedstock include soybean (US), rapeseed (Europe), oil palm (South-East Asia), jatropha curcus and rice bran oil (India). Biodiesel from canola, waste restaurant oil as well as animal fats have also been used in the existing CI engines without any modification (Widyan and Shyoukh, 2002; Chitra *et al*., 2005; Gupta *et al*., 2007; Krahl *et al*., 2005; Saravanan *et al*., 2007). In this work, biodiesel was produced through trans-esterification of POME with ethanol using KOH (potassium hydroxide) as catalyst.

MATERIALS AND METHODS

Raw palm oil mill effluent (POME) was collected from a local palm oil mill in Iranyin village, Ogbomoso, Oyo state in Nigeria. Analytical grade ethanol, potassium hydroxide and n-hexane were purchased from a chemical store in Ogbomoso. The materials were transported to the Chemical Engineering laboratory in Ladoke Akintola University of Technology (LAUTECH) where the experiments were performed.

Extraction of oil was achieved using solvent extraction method with the aid of a soxhlet apparatus. The feed oil to solvent ratio used was 3:1. N-hexane reagent of 80 ml was then added to 240 ml of feed oil and heated for 60 minutes to a temperature of 75^{o}C.

The trans-esterification process was carried out using a simple technology reactor of a fabricated 250 ml cylindrical tin equipped with a cake mixer which serves as the shaker. Pre-treatment operation was carried out by heating the bio-oil to a known temperature of about 65 ^{o}C using a Bunsen burner. This was done to ensure the remaining solvent, moisture content or other volatile impurities are removed. The bio-oil to ethanol ratio is 6:1. A constant volume of 150 ml of bio-oil was measured and poured into a glass beaker and heated to a temperature of 65^{o}C. Thereafter potassium hydroxide pellet of 0.046 g was measured and added to a constant quantity of 25 ml of ethanol corresponding to the used reaction mechanism and mixed thoroughly using the cake mixer to form potassium ethoxide. The potassium ethoxide solution and the heated raw bio-oil were mixed together in the reactor and the reactants were stirred for a reaction time of 60 minutes for the first run. Once the reaction time was complete, distilled water of 10% of the whole mixture was added and stirred again for 10 minutes to enhance easy settling and phase separation of the biodiesel and glycerol. The product mixture was poured into the separating funnel and left for 24 hours to settle. The whole process was repeated for a reaction time of 90, 120 and 150 minutes.

Once the reaction was complete, two major products were formed, glycerine and biodiesel. The mixture was then poured inside a closed glass 250 ml separating funnel and was left for 48 hours until a clear solution was obtained. The clear liquid (ethyl ester) found at the top layer was decanted into a graduated beaker (NBB). The separating funnel has a tap at its bottom which was used to separate the mixture inside the separating funnel by opening or closing of the tap.

The percentage biodiesel yield for each of the experimental runs was determined using equation 1.

$$\text{Biodiesel yield} = \frac{\text{Volume of biodiesel produced X 100\%}}{\text{Volume of oil used}} \quad (1)$$

The following physicochemical properties determined include specific gravity, cloud point, point pour and viscosity according to ASTM D standards at the Chemical Engineering laboratory, LAUTECH.

The sample of biodiesel (80% by volume) obtained at a reaction time of 120 minutes was used to run a dynamometer at different engine speeds (1500-2300) rev/min in the heat and mass transfer laboratory of Mechanical Engineering, LAUTECH.

RESULTS AND DISCUSSIONS

Table 1 shows the results of the biodiesel produced from the extracted oil at various reaction times. The production of biodiesel from the POME extracted oil using ethanol and potassium hydroxide as catalyst at a reaction time of 60, 90, 120 and 150 minutes gave a biodiesel yield of 61, 68, 80 and 75% respectively as an average of the three runs performed under the stated conditions. This shows that biodiesel yield is optimal at a reaction time of 120 minutes. Hence, any increase above this optimal reaction time does not necessarily result in an increase in biodiesel yield but could rather increase the cost of production of biodiesel.

Table 1: Results of Biodiesel Produced at Different Reaction Time.

Experimental Conditions	Reaction time (minutes)			
	60	**90**	**120**	**150**
Reaction temperature (^{o}C)	65	65	65	65
Volume of bio-oil (ml)	150	150	150	150
Volume of ethanol (ml)	25	25	25	25
KOH quantity (g)	0.086	0.086	0.086	0.086
Biodiesel obtained (ml)	91.5	102	120	112.5
Glycerol obtained (ml)	77.5	65.9	49.5	54.2
Losses (ml)	6	7.1	5.5	8.3
Biodiesel yield (%)	61	68	80	75

The losses accounted for occurred during the washing process, emission and from un-reacted reagents. The glycerol obtained can be used for making soap and in chemical industry.

The results fuel characterization performed on POME bio-diesel produced from the optimal reaction time and Petroleum diesel were presented Table 2. It is observed from Table 2 that the flash point obtained for POME bio-diesel (155 ^{o}C) is higher than that of conventional petroleum diesel (73 ^{o}C). This shows that the fire hazard associated with the use of POME bio-diesel is less than that of petroleum diesel. The pour point for palm oil bio-diesel (-7.1 ^{o}C) is higher than that obtained for petroleum diesel (-15 ^{o}C). The cloud point obtained for the palm oil bio-diesel (5.0 ^{o}C) is higher than that obtained for petroleum diesel (-10 ^{o}C) Therefore, with 5 ^{o}C cloud point for the POME bio-diesel, the fuel can be best used in diesel engines in both temperate and tropical regions of the world. Viscosity of POME bio-diesel produced (6.760) is higher than that of petroleum diesel (3.860). The shows that bio-diesel from POME is more viscous than petroleum diesel. The implication of higher viscosity is that it decreases the leakages of fuel in a plunger pair and in turn it changes the parameters of a fuel supply process. The specific gravity obtained for POME bio diesel (0.865) is slightly more than that of the petroleum diesel (0.835). This means that bio-diesel is slightly denser than conventional petroleum diesel.

Table 2: Physicochemical Properties of the Biodiesel Produced and Petroleum Diesel.

Property	Pome biodisesel	Petroleum diesel
Viscosity (PaS)	6.760	3.860
Specific Gravity	0.865	0.835
Flash Point (^{o}C)	155	73
Pour Point (^{o}C)	-7.1	-15.0
Cloud point (^{o}C)	5.0	-10.0

Table 3: Engine Performance Test for the Optimum Biodiesel Yield Produced Using a Dynamometer.

Engine Speed (Rev/min)	Power (kW)	Torque (Nm)
1500	46.5	291
1700	55.0	275
1900	59.0	250
2100	61.5	228
2300	68.0	209

Table 3 shows the results of torque output and power against the engine speed for POME bio-diesels. It is observed that the power outputs increases as the speed of the engine increases while the torque output decreases.

CONCLUSIONS

Excessive increase in temperature above the evaporating temperature of ethanol will subsequently reduce yield due to gradual evaporation of ethanol. The experiment has revealed that reaction temperature of 65 ^{o}C with bio-oil to ethanol ratio of 6:0 will give considerable bio-diesel yield. Similarly, soap and gel may be formed when catalyst amount increases beyond the optimum, this prevents ester layer separation. Excessive increase in reaction time above 120 minutes will lead to subsequent decrease in biodiesel yield. The engine performance test using the optimum biodiesel produced revealed a direct relationship between the power output and the speed of the engine, but otherwise with the torque output.

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