Comparatives Study of Production Biodiesel from Soybean oil and Jatropha Curcas Seeds Oil

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ABSTRACT

This study involves transesterification of soybean and Jatropha oils with methanol, using sodium hydroxide as the catalyst to produced biodiesel as an alternative to petroleum diesel. This work investigates the effects of temperature and time on the production of biodiesel from the feed stocks employed. Also investigated are the effects of particle size and temperature on the production of oil from the Jatropha seed. The produced biodiesels from soybean and Jatropha oil were characterised to determine their suitability as a replacement for the petrol diesel. Results obtained shows that both temperature and time influence the production of biodiesel from the soybean and Jatropha oil. Analyses of the produced biodiesels also indicates that the properties of the biodiesels produced shows that the density, refractive index, moisture content, viscosity, flash point, cetane number, pour point and sulphur content of the biodiesel produced from soybean oil are 0.882g/cm^3, 1.486, 0.018%, 6.24cP, 148°C, 51.3, –8.2 and 0.004% respectively. While the corresponding values of these properties for the biodiesel produced from Jatropha oil are 0.861g/cm^3, 1.532, 0.013%, 2.8cP, 89°C, 49.5, –7.9 and 0.001%. It can be inferred from the results on the properties of biodiesel that the properties of the produced biodiesels from soybean and Jatropha oils fit well within the set limits for the standard biodiesel and fossil diesel, the biodiesel can therefore be used as a replacement for the petrol diesel. Results of various analyses conducted on the biodiesels produced from soybean and Jatropha oil shows that biodiesel of good qualities can also be produced from the Jatropha oil and can be used as a substitute for production of biodiesel from soybean which is edible oil.

Keywords: Soybean oil, Jatropha oil, biodiesel, petroleum diesel, properties

INTRODUCTION

Recent petroleum crises, increasing cost and unavailability of petroleum diesel gave impetus to the search for an alternative fuel. Also, energy production has primarily been based upon the combustion of fossil fuels and coal [1, 2]. These resources are finite and pose significant environmental impact from their combustion while coal is predicted to be a viable energy resources for 90-200 years, it has been predicted that the world oil supply is reaching its peaks [3]. As oil is consumed, extraction becomes difficult and price rise gradually, hence the consumers are force to look for more economical methods of sourcing for energy [4, 5]. The environmental impact associated with fossil fuel is also another concern about its use as sustainable energy resources [6, 7]. The consequence effects of environmental pollution from the combustion of fossil fuel lead to increasing campaign for cleaner burning fuel in order to safeguard the environment and protect man from the inhalation of genotoxic substances [8, 9]. The exhaust from petroleum product, especially diesel is known to be toxic and carcinogenous in nature since they contain polycyclic aromatic hydrocarbon. The environmental effects and oil crises motivate the researchers and government agencies worldwide to work on an alternative fuel source known as biodiesel, which has been gaining popularities especially in advanced nations. [10]

Biodiesel is a potential substitute for petroleum diesel because it is made from renewable source and it is non-toxic biodegradable, nonflammable with fewer emissions, hence the use of biodiesel will help to reduce air pollution. Biodiesel is produce from vegetables oils such as soybean, palm oil, sunflower seed, and animal fats [11, 12]. In most developed countries, biodiesel is produced from edible oil such rapeseed, soybeans, corn and peanut. Because edible oils are already in high demand for consumption as food especially in developing countries, there is the need to produce the biodiesel from non-edible sources. The war of energy versus food remains a source of disunity and conflict between the rich and poor nations. It is only few rich nations that favored the production of biodiesel from edible oils as a means of controlling the carbon emission, while most part of the world favored the use of edible oils for consumption to prevent malnutrition. Among the various non-edible sources, Jatropha Curcas is identified as potential biodiesel source. It is a member of the Euphorbiaceous and it thrives on poor soil even in times of drought because of the water retaining fibers in its root, trunk and branches. It is well adaptable, does well on marginal land and can be used in reforestation scheme [13]. This study therefore, focus on the comparative analysis of biodiesel produced from Soybean and Jatropha Curcas seed using esterification method of converting oil to ester and glycerol with sodium hydroxide as the catalyst.

EXPERIMENTAL SETUP

All the chemicals use in this study is analytical grade (98-99.5%). It includes sodium hydroxide, methanol and petroleum ether. Soybean was obtained in the market, while Jatropha Curcas was gotten from an open field, in Kwara State of Nigeria.

Series of experiments include, extraction of oil from Jatropha seeds, transesterification of the oil from Soybean and Jatropha oil to produce biodiesel, washing of biodiesel to remove the impurities and characterizations of biodiesel to determine its suitability as an alternative to petrol diesel

EXTRACTION OF OIL FROM JATROPH CURCAS SEEDS

Prior to the extraction, the Jatropha seeds were crushed with a mallet on a clean surface and the shells were separated from the inner seed by hand picking. The whitish inner seeds were kept in a polythene bag and dried in the oven at 100°C for 3-5 hours. The seed were then blended into different particle sizes. After the oil producing seed has been separated from the shell and dried, the seed was blended with a slow spinning blender and with different sizes of sieve filter to separate the blended seed into various size samples (500μm, 710μm, 850μm, 2.36mm). The empty thimble to be used for the different particle sizes was weighed and re weighed when the seed particles of a known mass were filled into different thimbles and were weighed. This was then followed by addition of 150cm^3 of petroleum ether into round bottom flasks which serve as extracting solvent and the soxhlet apparatus was set up and heated for 6 hours at different temperature for each run of the extraction. After each extraction round, the sample (shaft) was dried in an oven and the percentage yield of the oil was recorded.

BIODIESEL PREPARATION

A known volume (2000cm^3) of soybean and Jatropha oils was heated in a different container to 60°C and maintained for 60 minutes. The heated oils were poured in to a settling tank and left to settle down for 30 hours, not more than 90% of the settled oil was decanted from which 1500cm^3 was measured. The free fatty acid level was determined using titrimetric method in order to calculate the amount of dilute sodium hydroxide solution that will be enough to neutralize free fatty acid. The actual biodiesel production involves mixing the methoxide (Reaction between the catalyst, sodium hydroxide and methanol) with 1500cm^3 of soybean and Jatropha oils that were earlier decanted and mixing properly using a stirrer while heating slowly between 40°C and 60°C in order to avoid the evaporation of methanol in the mixture. The mixture was allowed to stand for 48 hours before, after which the reaction mixture was poured into another plastic container and transesterification thrice for proper phase separation and maximum conversion.

The crude biodiesel was washed with 750cm^3 of clean water by stirring and allowed the water to settle down before removing and drilling to eliminate traces of soap formed.

WASHING AND CHARACTERIZATIONS OF BIODIESEL

The crude biodiesels produced from Soybean and Jatropha oil were washed separately with 750cm^3 of clean water by stirring gently and allowed to settle down for about 3-4 hours. The two phase mixture was then separated using a separating funnel. This was then followed by microwave heating of the mixture at 60°C for 3-4 minutes to remove the residual methanol and water. To confirm the suitability of the biodiesel as an alternative to petrol diesel, the properties such as pour point, flash point, density, viscosity, cetane number and distillation characteristics were investigated [4,5].

RESULTS AND DISCUSSION

Diesel is mainly consumed for the transportation of industrial and agricultural goods and operation of diesel tractors, but today, transport sector consume about 25% of the total energy. Of this amount, transport use almost 75% while the railway account for the rest. Economic growth is important for the sustenance and development of a nation, but it is always accompanied by commensurate increase in the transport area. Thus, the cost of transportation affects the cost of all other consumable and non-consumable materials that reach the common man, as such short terms measures can have adverse implication on industrial and economic growth. Consequently, the continued shortage of petrol and diesel would create bottlenecks in transportation leading to an all round dislocation of economic activity however, the only answer to the current oil crises and way out of the future energy and economic crunch, is to explore the feasibility of substitution of diesel with an alternative fuel, which can be produced locally by every nations on a massive scale to commercial utilization. In this content, it is significant to point out that, edible oils have been adopted by few developed nations to produced biodiesel, the development that resulted into violent criticisms from developing nations and various nongovernmental organizations. It was argued that the technology of producing biodiesels from edible oils will cause food shortage, which they consider more important than the fuel shortage. It is therefore important to investigate the possibility of producing biodiesel of good qualities from non edible oil. The non-edible vegetable oil of Jatropha Curcas has the requisite potential to provide a promising and commercially viable alternative to diesel as it has the desirable physico-chemical and performance characteristic, comparable to diesel. According to the industries of Osaka Municipal Industry Japan, Jatropha oil contains 21% saturated fatty acid and 79% unsaturated fatty acid [14, 15]. This study is aim at investigating the extraction of oil from the Jatropha seed, and used the oil extracted to produce biodiesel, it also aimed at compare the properties of biodiesels produced from Jatropha oil with that of soybean oil which is edible oil and results obtained are presented.

The result obtained from the solvent extraction of oil from Jatropha Curcas seeds are shown in Table-1, for which different sample sizes and temperature were used to ascertain its effect on the oil yield. From the results, it can be deduced that for solvent extraction, sample size and temperature are both limiting factors on oil yield. For instance the effect of size on extraction of oil reveals that the highest percentage of extraction was obtained from the particles size of 500μm which is the smallest particle size. This pattern of results can be attributed to the fact that smaller particles with larger contact are less resistant to the solvent entrance and the amount of the oil that will be transferred from the smaller particles to the surrounding solution will be higher in comparison to the larger particles size. Also presented in Table 1 is the effect of temperature on the percentage of oil extracted from the Jatropha seed. It can be observed from the results presented that all particle sizes, the percentage yield of oil increases with increase in temperature. Increase in temperature enhanced the diffusion coefficient and solubility of the oil in the solvent, and increase the extraction rate.

Table 1. Result of solvent extraction of Jatropha Curcas

Sample	Percentage yield at varying temperature			
	50°C	60°C	70°C	80°C
A	40.20	44.92	45.20	46.50
B	40.42	43.50	44.56	46.33
C	40.10	43.10	44.13	45.47
D	40.00	42.00	44.29	45.00

Sample A: 500µm, B: 710µm, C: 850µm, D: 2.36mm

Results obtained on the effect of temperature on the transesterification of soybean and Jatropha oils are presented in Tables 2 and 3 respectively. It can be seen that the temperature clearly influenced the rate of production of biodiesel from the oil samples, as the temperatures increases the yield of biodiesel also increases. This can be attributed to the fact that increase in temperature cause fast formation of emulsion that is easily break down to form a lower glycerol rich layer and upper methyl rich layer. The formation of emulsion are caused in part by the formation of the intermediates, mono-glycerides and di-glycerides, which have both polar hydroxyl and non polar alcohol phase in which triglycerides must transfer in order to react. Results obtained on the production of biodiesel from Jatropha seed also increase as the temperature increases from 50 to 60°C, after which the production started reducing. This implies that above 60°C, the reaction rate favored more of the glycerin and not the biodiesel.

Table 2. Effects of temperature on the production of biodiesel from Soybean

Temperature (°C)	Volume before washing	Volume after washing	Volume yield	Mass	Moles	Mol. Yield
30	31.50	24.50	0.6125	21.56	0.0726	1.513771
40	29.00	26.00	0.65	23.92	0.0805	1.679471
55	31.00	27.40	0.6625	25.97	0.0874	1.823406
70	32.50	29.00	0.725	26.68	0.0898	1.873257
80	32.70	29.20	0.73	30.705	0.1034	2.15586

Table 3. Effects of temperature on the production of biodiesel from Jatropha Curcas oil

Volume sample	Temperature °C	Volume of glycerin	Volume of biodiesel
50	50	28	105
50	60	30	130
50	70	39	119
50	80	82	40

CHARACTERIZATIONS AND COMPARATIVE STUDY

Biodiesel has been gaining world wide popularity as an alternative energy source because it is made from renewable sources, non toxic, biodegradable, non flammable and has significantly fewer emissions. Biodiesel is produced through transesterification reaction of vegetable oil and fats with alcohol of low molecular weight either methanol or ethanol, with alkaline, acid or enzyme as catalyst. Though, the addition of sodium hydroxide as catalyst help to increase the rate of production of biodiesel and also compensate for higher acidity but the resulting soap cause an increase in viscosity of formation of gels that interferes in the reaction as well as separation of glycerol. It is therefore important that correct amount of catalyst are used in the reaction. Results obtained on various analyses conducted on the properties of the biodiesel produced from soybean and Jatropha oils are presented in Table 4. As shown in Table 4, the results of properties of biodiesel produced from the soybean and Jatropha oils were compared with the standard values and that of the fossil fuel diesel. It can be seen from Table 4 that the density of the produced biodiesel from soybean was 0.882g/cm^3, while that of the biodiesel produced from Jatropha oil was 0.861g/cm^3. These values of density of biodiesels from the two stocks employed in this study are within the ranges of literature values of density of biodiesel (0.87-0.88g/cm^3). Also presented in Table 4 is the sulphur contents of biodiesel. It can be deduced from the results that the sulphur contents of the produced biodiesel (0.004% and 0.001% respectively for the biodiesel produced from soybean and Jatropha seed) are much lower than that of the standard value of the biodiesel (0.02%) and that of the petroleum diesel (0.05%). Higher levels of sulphur in the diesel are harmful to the environment; hence the uses of catalytic diesel particulate emissions as well as advanced technologies such as sulphur oxide absorber are employed to reduce emission from petrol diesel. The process of reducing sulphur contents of the fossil diesel also reduces the lubricity of the fuel which implies that additive need to be added to help lubricate the engine. The process of reducing sulphur contents in the fossil diesel therefore contribute to the cost of production, the low percentage of sulphur in the biodiesel will therefore reduce emissions of green house gases to the environment. Results presented in Table 4 also indicate that the viscosity of the biodiesel produced are 6.24 and 2.8cP for the biodiesel produced from soybean and Jatropha oil respectively. It can be seen from these values of the viscosity that the viscosity of the produced biodiesel from both stocks is within the range of the standard biodiesel (2-6.5cP). Compared the viscosity of the biodiesel to that fossil diesel, shows that the biodiesel produced from the Jatropha is lower than that of the petrol diesel (3.06cP), while that of the biodiesel produces from soybean was higher than that of the fossil diesel. Though, the viscosity of the biodiesel produced from Jatropha was lower than that of the petrol diesel, this will nevertheless aid pumping of fuel in an engine and reduce leakage [6].

Cetane number which is a measure of the ignition performance of a diesel fuel obtained by compare it to the reference fuels in a standardized engine test. Cetane for diesel engine is therefore analogous to the octane rating in a spark ignition engine, as it measures how easily the fuel will ignite in the engine. Results obtained as presented in Table 4 indicates that the cetane number of the produced are 51.3 and 49.5

for the samples obtained from soybean and Jatropha oils respectively, which are in the ranges of the cetane number of the standard biodiesel (46-52) and that of the fossil fuel diesel (48-52).

Table 4. Properties of biodiesel produced from the soybean and Jatropha oils compared with standard values and fossil diesel fuel

Parameters	Biodiesel (Soybean Oil)	Biodiesel (Jatropha oil)	Fossil fuel diesel	Standard Biodiesel
Density (g/cm^3)	0.882	0.861	0.856	0.87 – 0.88
Refractive Index	1.486	1.532	1.668	1.245 – 1.675
Moisture content	0.018	0.013	<0.2	0.05 maximum
Viscosity at 40°C (cP)	6.24	2.8	3.06	2.0 – 6.5
Flash point (^oC)	148	89	78°C	≥100°C
Cetane number	51.3	49.5	48-52	46-52
Pour point	-8.2	-7.9	-10	-21
Sulphur content (%)	0.004	0.001	0.05	0.02

Also presented in Table 4 are the refractive index, flash point, moisture content and pour point of the produced biodiesel from the stocks employed in this study. Flash point of the biodiesel produced from soybean and Jatropha oils are 148°C and 89°C, it can be deduced from these results that the flash of biodiesel from soybean is higher than the set limit of ≥100°C, while that of the biodiesel produced from the Jatropha oil is within the set limit. Though, higher flash point obtained from the biodiesel produced from soybean (>100°C) may be advantageous in the process of storage and transportation but the disadvantage is that it may create an initial starting problem in engine (Eneche, 2008). The results of the pour point of the produced biodiesels are -8.2 and -7.9 respectively for the biodiesel produced from soybean and Jatropha oil, compared with the standard biodiesel (-21) and fossil diesel (-10), it can be concluded that the pour point of the produced biodiesels are closer to that of fossil diesel. The refractive index is important parameters used to measure the origin of the diesel; it is therefore allow the users to differentiate and identify the sources of the oil. Results obtained on the refractive index of the biodiesels produced from the soybean and Jatropha oils are within the set limit and slightly lower than that of the fossil fuel diesel. The results obtained on the moisture contents of the produced biodiesels shows that they are within the set limit of both the standard biodiesel and fossil diesel. Therefore, from the results of various analyses conducted on the biodiesel produced from the soybean and Jatropha oils, it can be concluded that the biodiesel can serve as alternative to the fossil fuels diesel. Results of the analyses also indicate that the biodiesel produced from Jatropha seed can be used as a substitute for the soybean which is edible oil. We summarize the results next.

CONCLUSIONS

Based on the results obtained from this research on the production and characterization of biodiesels from soybean and Jatropha oils, it can be concluded that oils from both feed stocks are suitable for the production biodiesel. The physicochemical properties such as density, viscosity, sulphur content, moisture content, cetane number, viscosity, flash point and pour point of the biodiesels produced from soybean and Jatropha oil conforms to the set limit for both the standard biodiesel and petrol diesel. The biodiesel produced can therefore be used as a substitute for petrol diesel, the Jatropha seed oil can also serve as a substitute for the soybean which is edible oil.

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