Production of Biodiesel from Some Vegetable Oils

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ABSTRACT

Biodiesel is becoming prominent among the alternatives to conventional petro-diesel due to economic, environmental and social factors. The quality of biodiesel is influenced by the nature of feedstock and the production processes employed. High amounts of free fatty acids (FFA) in the feedstock are known to be detrimental to the quality of biodiesel. In addition, oils with compounds containing hydroxyl groups possess high viscosity due to hydrogen bonding. American Standards and Testing Materials, (ASTM D 6751) recommends FFA content of not more than 0.5% in biodiesel and a viscosity of less than 6 mm2/s. The physico-chemical properties of palm kernel oil and coconut oil were assessed for their potential in biodiesel. The properties of palm kernel oil and coconut oil were compared with those of palm from literature while that of biodiesel were compared with petro-diesel, ASTM and European Standards (EN14214). Results showed that high amounts of FFA in oils produced low quality biodiesel while neutralized oils with low amounts of FFA produced high quality biodiesel. The quality of biodiesel from palm kernel oil and coconut oils was improved greatly by neutralising the crude oils

Keywords- Feedstock; biodiesel; physico-chemical properties; transesterification

INTRODUCTION

Vegetable oils are among the various sources of energy fuels being considered as alternatives to fossil fuels. Rapeseed, soybean, sunflower, coconut and palm oils and other vegetable oil have been the main raw materials for biodiesel production. However, these oils are required in refined forms to obtain quality biodiesel and, in addition, they are foodstuffs. This makes production of biodiesel from these sources uneconomical. Non-edible plant oils such as found in jatropha curcas and castor beans may provide better alternatives. There is a need for alternative energy sources to petroleum-based fuels due to the depletion of the world's petroleum reserves, global warming and environmental concerns. Biodiesel is a clean and renewable fuel which is considered to be the best substitution for diesel fuel (Singh & Singh, 2010).

Soybean oil is one of the major feedstocks for biodiesel production.

According to United States Department of Agriculture (USDA), the U.S. was the largest producer of soybean oil in the world in 2006/2007. The U.S. was followed by Argentina, China, Brazil and India in soybean oil production. The U.S. produced 34.5 % of total soybean oil in the world (United States Department of Agriculture, 2008). This amount of oil is a promising source for biodiesel production from a natural and environmentally friendly agricultural product (Patil & Deng, 2009). Although Food and Agriculture Organization of the United Nation (FAO) stated many environmental problems associated with large scale production of soybeans and maize (FAO, 2009), Life Cycle Assessment (LCA) studies indicated that cultivation of soybeans has less negative impacts on environment than some other oil seeds like sunflower and rapeseed (Sanz Requena et al.,2010).

In addition to biodiesel production, soybeans can be used to produce ethanol. Soybean hulls contain significant amount of carbohydrate for ethanol production and producers prefer to use soybean hulls for animal feeding because of its high protein content (Mielenz et al., 2009). Although, biodiesel is usually used as a blend with petro-diesel at varying ratios, it can also be used to fuel compression ignition engines alone. The results of engine emission tests showed that use of biodiesel alone produced less emissions of CO, HC, NOx and smoke than petro-diesel (Qi et al., 2009).

Conventional biodiesel production from soybeans uses separate processes for oil extraction and biodiesel conversion. Oil extraction from soybeans is accomplished by using mechanical presses, solvent extraction, supercritical fluid extraction and microwave- and ultrasound-assisted solvent extractions. The extracted oil is degummed and converted to biodiesel via transesterification. Transesterification is a chemical reaction process during which the oil is combined with alcohol, usually ethanol or methanol, in the presence of a catalyst to form fatty esters and glycerol. Reducing biodiesel production costs from $ 3.11 per gallon to below the petro-diesel cost of $3.0 per gallon is important to make biodiesel competitive in the diesel fuel market (Kargbo, 2010).

The objective of this chapter is to provide a literature review on oil extraction and biodiesel production from soybeans and to discuss the uses of high intensity ultrasound in processing of soybeans for biodiesel production. Three examples of ultrasound applications in soybean processing for biodiesel production will be discussed. The first example will investigate the effects of solvent amount, oil extraction time and ultrasonication on soybean oil yield. The second example will examine the ultrasound-assisted transesterification of soybean oil for biodiesel production. The third application will investigate the feasibility of integrating soybean oil extraction and biodiesel production processes using ultrasound-assisted *in-situ* transesterification.

Biodiesel is produced from a wide variety of vegetable oils including virgin oil feedstocks such as palm, soybean, rapeseed, mustard, peanut, coconut, olive, Jatropha, flax, sunflower, and cotton seed oils. Others are rubber seed, grape seed, hazelnut, linseed safflower, sesame, and corn and rice bran oils (Paynich, (2007). The use of these vegetable oils is considered a cheap source especially when they have been used for frying. The use of fry vegetable oils is also useful environmentally as a means of disposing off restaurant greases or domestic fry oil wastes and reducing the cost of waste treatment. (De Poola *et al*, 2009). Biodiesel is also produced from animal fats (Hilbert, et al. 2005) such as tallow, lard, yellow grease and chicken fat as well as the by-products of production of omega-3-fatty acids from fish oil. The production of biodiesel from algae has received a lot of publicity (Chrsti, 2007, Christi, 2008, Greenwell *et al*, 2010, Gordon, and Polle, 2007). The transesterification process usually involves the use of short chain alcohols such as methyl or ethyl alcohol and a catalyst is normally used to speed up the reaction. The catalyst can be a base or acid or enzymes such as lipase and many others (Shimada *et al*, 2002).

Acid catalysis is viewed as being too slow kinetically. The use of bases as catalysts has the problem of substrate loss through soap formation, high viscosity, formation of gels and the difficulty in separation of glycerol which is formed as a byproduct. The alternative enzymatic catalysis has the advantage of the possibility of carrying out the reactions at low temperatures (Paynich, 2007). Also the enzymes such as lipase can catalyse the transesterification of free fatty acid (Kumari *et al*,2007; Kaieda *et al*, 2001)

.The other advantage is higher yields of esters comparatively, and the recovery and reuse of enzymes. However, the cost of the enzymatic process is still too high (Hernández-Martín and Otero, 2008).

In this paper we have used fresh palm kernel oil, coconut oil and the base catalysis process which still seem to be the best practical option. We have examined the diesel quality characteristics of the biodiesel produced from these vegetables oil at different stages of use in frying relative to the biodiesel produced from the fresh palm kernel oil.

MATERIALS AND METHODS

Materials

Palm kernel oil (PKO) and Coconut oil (COCN) were sourced at a local oil producing firm in Osun State. 500 ml beaker, and 250 ml beakers, stand and clamp, electronic weighing balance (0.001- 300 g), reagent bottles, thermometer, conical flask, separation funnel, hot plate with magnetic stirrer, test tubes of different sizes and funnel. All chemicals including methanol (CH_3OH) and sodium hydroxide (NaOH) are of commercial grade from BDH Laboratory Chemicals.

EXPERIMENTAL PROCEDURE: Test batch - 200ml of palm kernel oil, coconut oil and 40 ml of methanol (i.e 20% by volume of oil) were utilized in the test batch production. 200 ml of palm kernel oil was pre-heated to a steady temperature of 60oC using a magnetic heater/stirrer. With the aid of the measuring cylinder 40 ml of methanol was measured and poured into the beaker. 0.7g of NaOH pellet was measured using the weighing balance and added to the methanol. The content of the beaker was stirred vigorously using the second magnetic stirrer until the NaOH was completely dissolved in the methanol. The mixture formed is called Sodium Methoxide. The Methoxide was poured into the conical flask containing the preheated oil. The content of the conical flask was stirred with the magnetic stirrer at a steady speed and temperature of 55oC. Then heating and stirring was stopped after 2 hours and the product was poured into a separating funnel mounted on a clamp stand. The mixture was allowed to settle down from 4:25pm to 10:10 am the following morning. The separating funnel was opened at the bottom allowing the glycerin at the bottom to be run off after which the biodiesel was collected in a beaker after which it was poured into a container for storage.

Final production batch: The test batch just described above was performed in order to have a firsthand experience of the reaction methodology and its attendant products. It serves as a means of ensuring that the end products can be successfully obtained from the reactants. Based on the successful results obtained from the test batch reaction, the final production batch was carried out using the same volume and/or mass of reactants and the separation of the products was carried out as already described for the test batch production. The procedure was replicated three times and average biodiesel yield as well as glycerol yield was measured. The steps described above i.e. the test and final production batches were repeated for coconut oil, cashew nut oil, and soya oil. The schematic diagram of the experimental set-up is shown in Figure 1.

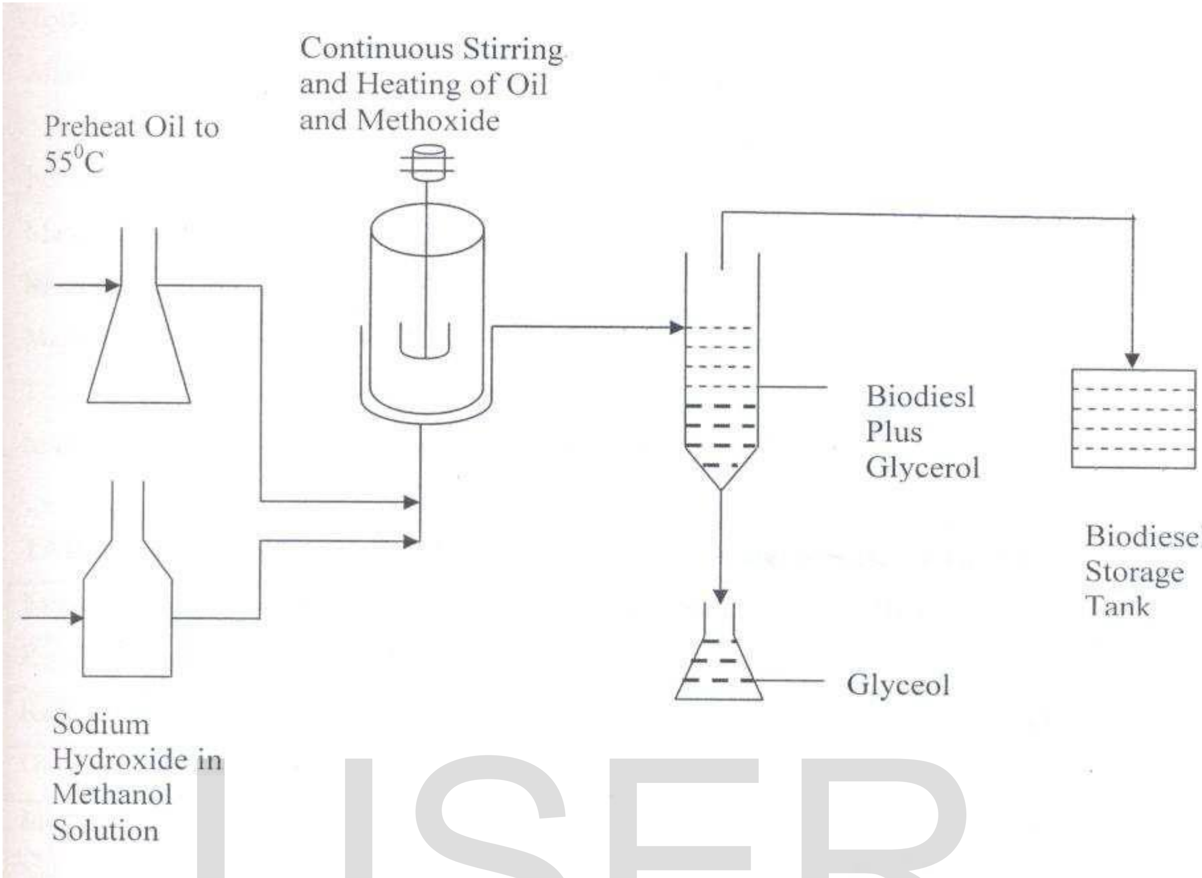

Figure 1: Schematic diagram of the unit for biodiesel production

RESULTS AND DISCUSSION

The result of the study are presented in the table and below which shows the mean and stand and deviation of the physicochemical properties of biodiesel from palm kernel oil and coconut oil samples purchased in Osogbo.

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PHYSICOCHEMICAL PROPERTIES OF BIODIESEL PRODUCT FROM PALM KERNEL OIL AND COCONUT OIL

S/N	PARAMETER	PKO	COCN	DIESEL STANDARD
1.	pH	7.280±0.00	8.030±0.00	5.00±0.01
2.	COLOUR (VISUAL)	LIGHT YELLOW	LIGHT YELLOW	DARK BROWN
3.	REFRACTIVE INDEX	1.348±0.00	1.351±0.00	1.47±0.01
4.	SPECIFIC GRAVITY (g/dm^3)	0.905±0.00	9.934±0.00	0.85±0.01
5.	VISCOSITY (U^2 / Sec)	41.440±0.00	10.570±0.00	5.89±0.01
6.	SMOKE POINT (˚C)	-	-	80.00±0.20
7.	FLASH POINT (ºC)	68.00	130.00	105.00±0.00
8.	FIRE POINT (ºC)	-	-	105.00±0.00
9.	CLOUD POINT (ºC)	-5.800± N.A	-8.200± N.A	26.00±0.00
10.	POUR POINT (ºC)	8.000± N.A	4.300± N.A	4.00±0.00
11.	ACID VALUE (mg/g)	15.177	14.278	1.12±0.01
12.	FREE FATTY ACID (mg/g)	7.627	7.175	0.56±0.01
13.	PEROXIDE VALUE (mg/kg)	172.800	53.600	3.20±0.01
14.	IODINE VALUE (mg/g)	71.219	62.474	17.13±0.08
15.	SAPONIFICATION (mg/g)	456.340	431.970	100.98±0.03
16.	ESTER VALUE (mg/g)	441.163	417.692	99.86±0.01

MEAN±STANDARD DEVIATION

PKO - (PALM KERNEL OIL), COCN- (COCONUT OIL), N.A- NOT AVAILABLE

DISCUSSION

PALM KERNEL OIL AS BIODIESEL

Palm kernel oil is an edible plant oil derived from the kernel of the oil palm *Elaeis guineensis*(Poku, and Kwasi (2002). Palm kernel oil, coconut oil, and palm oil are three of the few highly saturated vegetable fats; these oils give the name to the 16-carbon saturated fatty acid palmitic acid that they contain. Palm kernel oil, which is semi-solid at room temperature, is more saturated than palm oil and comparable to coconut oil. It is commonly used in commercial cooking because of its relatively low cost, and because it remains stable at high cooking temperatures and can be stored longer than other vegetable oils. Palm kernel oil, like other vegetable oils, can be used to create biodiesel for internal combustion engines. Biodiesel has been promoted as a renewable energy source to reduce net emissions of carbon dioxide into the atmosphere. Therefore, biodiesel is seen as a way to decrease the impact of the greenhouse effect and as a way of diversifying energy supplies to assist national energy security plans. Palm is also used to make biodiesel, as either a simply-processed palm kernel oil mixed with petro-diesel, or processed through transesterification to create a palm kernel oil methyl ester blend, which meets the international EN 14214 specification, with glycerin as a byproduct. The result shows that biodiesel from palm kernel oil has a very high viscosity, saponification value, acid value, Peroxide value, Ester value, Iodine value, pour point, and free fatty acids.

COCONUT OIL AS BIODIESEL

Coconut has an Oil content of about 70%. The Cetane Number (60) and Iodine Value (10) of coconut oil/copra oil are within acceptable limits for use in diesel engines. Its viscosity after trans-esterification is also in the acceptable range. It thus appears to be a good candidate for biodiesel. According to some reports, “Unlike with many biofuels, coconut oil doens't need to be transesterized - mixed with sodium hydroxide and alcohol to change its chemical composition - to run in a diesel engine. Filtered and warmed to temperatures about 25C, coconut oil is a better than satisfactory substitute for "mineral diesel" - it burns more slowly, which produces more even pressure on engine pistons, reducing engine wear, and lubricates the engine more effectively.

Physical properties

Coconut oil is a fat consisting of about 90% saturated fat. The oil contains predominantly medium chain triglycerides, with 86.5% saturated fatty acids, 5.8% monounsaturated fatty acids, and 1.8% polyunsaturated fatty acids. Of the saturated fatty acids, coconut oil is primarily 44.6% lauric acid, 16.8% myristic acid and 8.2% palmitic acid, although it contains seven different saturated fatty acids in total. Its only monounsaturated fatty acid is oleic acid while its only polyunsaturated fatty acid is linoleic acid.(Nutrient analysis of coconut oil – USDA). Unrefined coconut oil melts at 20-25 °C and smokes at 170 °C (350 °F).(Cooking For Engineers - Kitchen Notes: Smoke Points of Various Fats), while refined coconut oil has a higher smoke point of 232 °C (450 °F). Coconut oil has a long shelf life compared to other oils, lasting up to two years due to its resilience to high temperatures. Coconut oil is best stored in solid form - i.e. at temperatures lower than

24.5 °C (76°F) in order to extend shelf life. However, unlike most oils, coconut oil will not be damaged by warmer temperatures.

Chemical properties

Among the most stable of all vegetable oils, coconut oil is slow to oxidize and thus resistant to rancidity.

CONCLUSION AND RECOMMENDATION

CONCLUSION

This study revealed that biodiesel could be produced successfully from palm kernel and coconut oil, by alkali- catalyzed transesterification. The effects of different parameters such as reaction time, temperature, catalyst concentration and reactant ratio on the biodiesel yield were analyzed. The good combination of the parameters were found as 5:1 molar ratio of oil to methanol, 0.5% NaOH catalyst, 60°C reaction temperature and 2 hours of reaction time. The viscosity of the above vegetable oil will reduces substantially after transesterification and is comparable to petro-diesel and the physical and chemical properties of biodiesel produced conform to available standards.

Biodiesel-fueled vehicles can be called non-dedicated alternatively fuel vehicles because biodiesel use does not require any significant modifications to the engine, so that the engine does not have to be dedicated for biodiesel use only. It is completely soluble in commercial petroleum-based diesel fuel, so biodiesel can be used as a blend and one fuel tank can be used for storage of both fuels. This is a unique advantage compared with most other alternative fuels, because this will give users the opportunity to use the alternative fuel where and when it is available without paying any extra money for engine modifications. Many large engine and car manufacturers have included biodiesel fuel in their warranties (Korbitz, 1999). Depending on the trade-off between cost and its environmental benefits, biodiesel will be most commonly used in blends with No. 1 or No. 2 diesel fuels.

Biodiesel has different physical and chemical properties that provide its advantages over petroleum-based diesel fuel. However, these property differences can also provide disadvantages such as power loss and higher NOx emissions. Therefore, the blending effects on the fuel properties should be known and the detection of the blend level may be required in order to provide equal power and emissions.

RECOMMENDATION

The use of palm kernel oil and coconut oil, for the production of biodiesel is promising but with a slight change in palm kernel oil produced biodiesel because palm kernel oil solidifies at room temperature and cannot be effectively used in cold environment (areas). The biodiesel properties of the samples did not deviate significantly from expected values but vegetable oil gotten from jatropha and castor bean serve as better options for the production of biodiesel because they are not edible. They can hence be used as alternative fuel for diesel engines.

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