



Production of biodiesel from palm kernel oil (PKO) using sodium-ethoxide: The effect of time

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Abstract

In the production of biodiesel a wide variety of vegetable oils can be used as raw material. In this research palm kernel oil was used. The pure palm kernel oil could have been used as diesel but the viscosity would just be too high for application in engines and automobiles. In an attempt to modify (or improve on) the viscosity, transesterification was done with the aid of sodium-ethoxide; a blend of sodium hydroxide (NaOH) and ethanol (C₂H₆O). The effect of time on the yield and how it affects the viscosity of the PKO-biodiesel so produced was investigated. The biodiesel obtained had a viscosity that was less than that of the original PKO by almost 80%. And results obtained from the runs indicate that the yield is nearly independent on reaction time. © 2017 ijrei.com. All rights reserved
Keywords: biodiesel, transesterification, ethanol, palm kernel oil (PKO), glycerol, ethyl ester, viscosity

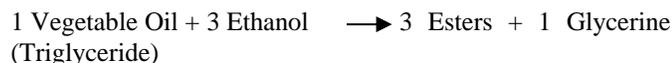
1. Introduction

It is no longer news that nowadays attention is focused on the search for cheaper, environmentally friendly and renewable sources of fuel by nations, organizations and individuals. This is basically as a result of the volatility of the world petroleum market caused by incessant rise in petroleum prices, increasing threat to environment from exhaust emissions, global warming and rapidly decreasing crude oil deposits amongst other factors. Among the different possible resources or raw materials diesel fuels derived from triglycerides of vegetable oils and animals fats have shown potential as substitute for petroleum-based diesel (PBD) fuels [1]. They are generally called biofuels. Modern biofuels have been reported as a promising long term renewable energy source which has potential to address both environmental impact and security concerns by current dependence on fossil fuels [2, 3]. A relatively recent popularized classification for liquid biofuels includes 'first-generation' and 'Second-generation' fuels. First generation biofuel sources are those made primarily from food crops such as grains, sugar beet and oil seeds (but they are limited in their ability to achieve targets for oil-product substitution; climate change mitigation, and economic growth) [4]. Second-generation energy crops are grouped into grassy (herbaceous or forage) and woody (tree) energy crops [5].

Microalgae are currently being promoted as an ideal third generation biofuel feedstock because of their rapid growth rate, CO₂ fixation ability and high production capacity of lipids. Moreover, these precursors do not compete with food or feed crops, and can be produced on non-arable land. [6] Currently most of the existing infrastructure is built to process biofuel from first generation sources. This is because the technology already available is more efficient for first generation than other generations. However, there are many unavoidable problems with the mass production of first generation biofuels sources which includes competition with other crops for land that could be used for food production; high input of fertilizers and pesticides, and increased erosion from tillage and putting poor quality land into production. But then, energy analysts [7,8] claim that the use of biomass for energy purposes could increase substantially, as a result of policies to curb growing emissions of CO₂.

In the early days of diesel engines, vegetable oils were tested (their original compositions unchanged) as a possible motor fuel but the idea never took hold owing to incompatibility problems such as high viscosity and deterioration of the oil with time [9]. For a number of reasons the biodiesel route has been reactivated recently: it has been found that vegetable oil

can be transformed via esterification into a product which is more adequate as a diesel fuel than the original oil itself; and that a wide variety of vegetable oils can be used as raw material for transesterification [10]. Hence, this study is aimed at showing the possibility of obtaining biodiesel with an improved viscosity; from palm kernel (vegetable) oil. The main disadvantages of vegetable oils as diesel fuel are higher viscosity, lower volatility, and the reactivity of unsaturated hydrocarbon chains [11, 12]. Diesel engines presently in use require a clean-burning, stable fuel operating under a variety of conditions. In the mid-1970s, fuel shortages spurred interest in diversifying fuel resources, and thus biodiesel as fatty esters was developed as an alternative to petroleum diesel. Satisfactory results have been recorded from short-term as well as long-term tests carried out on diesel engines using biodiesel from different feedstock as well as their blends with conventional diesel as fuel. It is also reported that Korus *et al.* (1995) conducted rapid engine test to measure injector fouling in diesel engines using vegetable oil fuels. While Peterson and Reece (1994) conducted tests on ethyl and methyl esters of rape-seed oil [13]. Transesterification of vegetable oil is sure way and most likely the most common means of producing biodiesel. Transesterification reaction involves the reaction of an alcohol (methanol or ethanol) with triglycerides of vegetable oils to form the corresponding alkyl ester and glycerine indicating the following reaction scheme



The global stoichiometry is of course an oversimplification as we are in presence of a three-step reversible reaction with di- and mono- glyceride (DG and MG) as intermediate products. The structures of mono-, di-, and tri-glycerides (MGs, DGs, and TGs) consist of glycerol (a backbone of carbon, hydrogen, and oxygen) esterified with fatty acids (chains of carbon and hydrogen atoms with a carboxylic acid group at one end) [14] as shown below

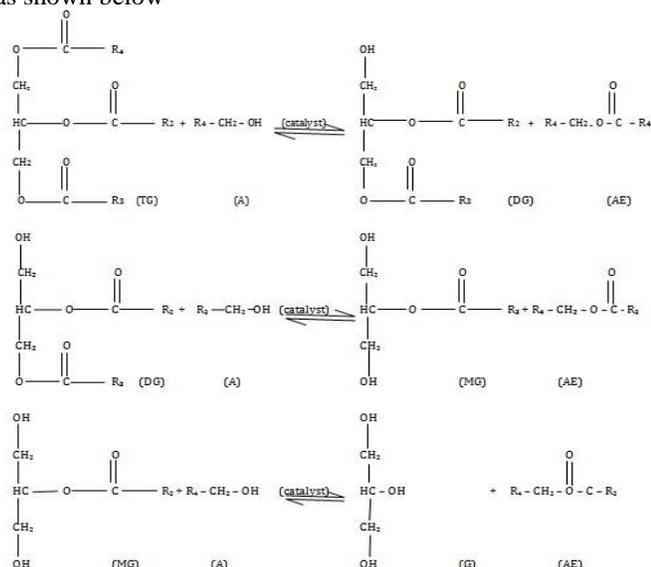


Figure 1: Three-step transesterification reactions.

The reaction takes place in the company of a catalyst that is most commonly sodium hydroxide, potassium hydroxide or sodium methylate. In the case of biodiesel production, the main objective is to achieve the maximum possible conversion towards alkyl ester (in excess of about 97%. The three equations above can be compressed in a row (using methanol as the alcohol) as shown in figure 2 below. When the reaction starts the triglycerides are converted to diglycerides, which in turn are converted to monoglycerides, and then to glycerol. Each step produces a molecule of a methyl ester of a fatty acid. If the reaction is incomplete, then there will be triglycerides, diglycerides, and monoglycerides left in the reaction mixture. Each of these compounds still contains a glycerol molecule that has not been released. The glycerol portion of these compounds is referred to as *bound glycerol* [15]. When the bound glycerol is added to the free glycerol, the sum is known as the *total glycerol* [16].

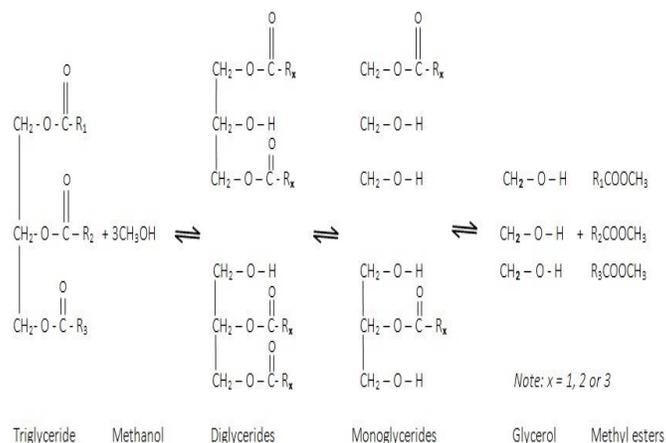


Figure 2: reactions in the transesterification process of a triglyceride.

2. Methodology

2.1 Materials Used

- (i) 200.0g of the PKO was used for the transesterification process (purchased from a local market in Nigeria.)
- (ii) The ethanol used (99% pure) was of analytical grade with boiling point of 78° (obtained from Petroleum Processing Laboratory, Niger Delta University.
- (iii) The NaOH used was also of analytical grade - a product of Aldrich Chemicals, England; obtained from Separation Processing Lab., Niger Delta University).
- (iv) PET bottles (75 cl) were used for the reaction.
- (v) Equipment and apparatus used include: viscometer, weighing device, heater, thermometer; spatula, funnel, filter paper, retort stand, separator funnel, and plus conical flask, measuring cylinder, beaker, masking tape and PET bottles (for storage).

2.2 Experimental procedure [17]

- (i) The PKO was filtered and heated near boiling to evaporate any water present.
- (ii) Sodium ethoxide was prepared in a PET bottle adding 1.0g of NaOH to 40.0g of ethanol (added first). Shaking was done for about 10 minutes for proper mixing.
- (iii) 200.0g of PKO was poured into a PET bottle.. Sodium ethoxide from the plastic container was carefully poured into the PKO, the PET lid was secured tightly and agitation was done.
- (iv) The agitation in the container was maintained for 30 minutes in the first case
- (v) A second set up was carried out for 60 minutes.
- (vi) The mixtures were poured from the PET bottle into a separator held standing by a retort for settling; the tap was screwed tightly.
- (vii) Phase separation commenced after about 10 minutes. But both contents were allowed to settle for 72 hours to ensure proper separation.

2.2.1 Parameter calculation

The important parameter in the process can be calculated from the following equations;

$$\text{PKO - biodiesel yield (\%)} = \frac{\text{quantity of PKO - BD(g)}}{\text{quantity of PKO used(g)}} \times 100 \quad 1.0$$

$$\text{PKO-biodiesel concentration (\%)} = \frac{\text{quantity of PKO-BD(g)}}{\text{productions total sum(g)}} \times 100 \quad 1.2$$

$$\text{Yield (\%)} = \frac{\text{total amount of products(g)}}{\text{total amount of reactants(g)}} \times 100 \quad 1.3$$

A flow diagram describing the biodiesel production process is as shown below;

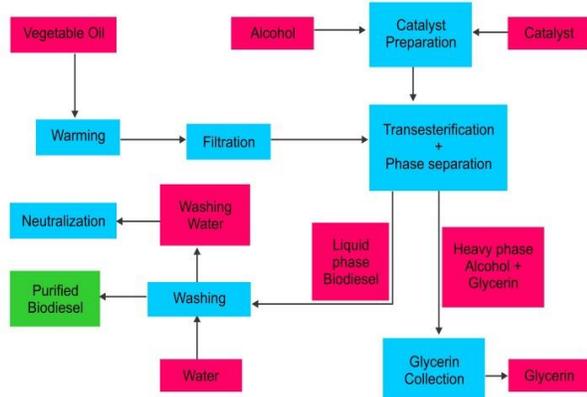


Figure 3: Flow diagram describing the biodiesel production process

3. Results and discussion

3.1 Viscosity and specific gravity tests

The transesterification process yielded 227 g PKO biodiesel

and 8.4g glycerol, while 5.51g of the total reacting masses could not be accounted for. For the second case the process yielded 22.42g PKO biodiesel and 11.12g glycerol with 7.46g loss recorded. These losses have been attributed to some unreacted alcohol, residual catalyst and emulsion removed during the washing stage of the production process [18]. Detailed results for each of the experimental runs are presented in Figure 4 below and the characterization results are tabulated in table 1.

Table 1: Fuel characterization results for PKO-biodiesel and petroleum diesel fuel.

Fuel characterization (Properties/parameters)	PKO Biodiesel	Petroleum Diesel	EN14214 European PD Standard	Rapeseed Biodiesel (ethyl Ester)	Canola Biodiesel (ethyl Ester)
Viscosity (@ 40°C), (mm ² /s)	7.42	2.847	3.50 -5.00	6.170	4.892
Specific gravity @ 15°C	1.176	0.853	0.86-0.90	0.876	0.878

3.2 Effect of reaction time

Results obtained from the two runs indicate that the yield is nearly independent of reaction time. That notwithstanding, increasing the reaction time results in decrease in ethyl ester concentration; ethyl ester yield, and the production yield. But the time change affected the methyl ester concentration more. A chart showing the different yields is presented below

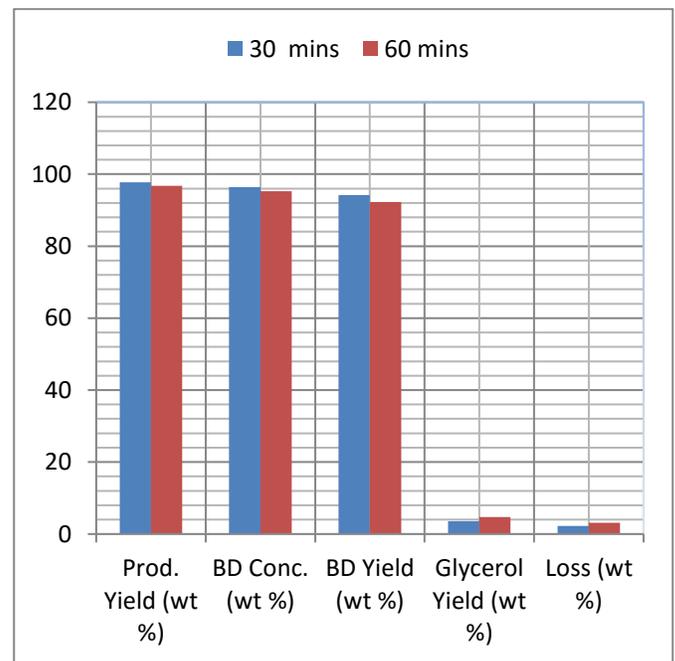


Figure 4: Effect of reaction time on methyl ester yield (using 1.0% NaOH at 30°C in a 5:1 (PKO:Ethanol) mixture)

The purpose of the transesterification of vegetable oils to biodiesel is to lower their viscosity. The PKO biodiesel produced and the commercial grade petroleum diesel were analyzed for basic fuel properties. Results obtained (for time variation) are presented in Table 1 - with raw PKO having a viscosity 3.33mm²/s, the PKO biodiesel viscosity obtained

showed (78%) reduction (i.e. 7.43 mm²/s). this will enhance the biodiesel's fluidity in diesel engines. And will solve the problem of too-high viscosity in vegetable oil, which has made them not suitable for direct use.

For the optimum time needed for the process, the results showed that there is no much effect when time is varied. However, keeping the reaction for too long would most likely cause reduction in the biodiesel yield. This reduced biodiesel quantity though would (most likely) increase the quality of the fuel obtained.

4. Conclusion and recommendation

Transesterification is a very sensitive process that requires extreme care as to the nature and state of the materials used as well as the reaction conditions. The process involves a straightforward series of chemical reactions, but many things can still go wrong in home (or laboratory) production setting. Understanding the likely causes of biodiesel failure can help rescue or at least prevent similar problems in the future.

Also, failed biodiesel may occasionally result in the production of something useful, like soap and lubricant (as suspected in this work). Recognizing when this happens can prevent the batch from becoming a total loss. For example, in one of the reaction settings (in this study) the reaction after being allowed to stay for days did not give any phase separation. In troubleshooting what went wrong it was observed the container of the NaOH used had some cracks which could have allowed moisture uptake from the atmosphere. This could also be as a result of water in the oil and or ethanol. But then the PKO used was de-watered; so suspicion that it had a problem is less likely.

Therefore, in the production of biodiesel, the alcohol used has to be very close to 100% alcohol. If exposed to the atmosphere, the Iye and alcohol would absorb water, which will prevent the biodiesel conversion.

4.1 Testing biodiesel for quality

No matter the route taken to produce biodiesel some common tests can be carried out to know whether what is produced is a biodiesel or whether it is of good quality [19].

- (i) Take a sample of the biodiesel and mix it with water in a test tube. Shake the tube vigorously. It should separate from the water very quickly. If it doesn't, the biodiesel contains too many contaminants and needs further cleaning before use.
- (ii) Take a sample of the drained wash water from the last washing cycle. Shake the sample of wash water vigorously. If it makes suds, soap is present and the biodiesel will need more washing.

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