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ORIGINAL ARTICLE

Effect of biodiesel production parameters on viscosity and yield of methyl esters: *Jatropha curcas*, *Elaeis guineensis* and *Cocos nucifera*

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Abstract In this study, the effect of H_2SO_4 on viscosity of methyl esters from Jatropha oil (JCME), palm kernel oil (PKOME) from *Elaeis guineensis* species, and coconut oil (COME) has been studied. Effect of methanol to oil molar mass ratio on yield of the three feedstocks has also been studied. Methyl ester yield was decreased by esterification process using sulphuric acid anhydrous (H2SO4). Jatropha methyl ester experienced a viscosity reduction of 24% (4.1–3.1 mm^2/s) with the addition of 1% sulphuric acid. In this work palm kernel oil (PKOME), coconut oil (COME) and Jatropha oil (JCME) were used as feedstocks for the production of biodiesel to investigate optimum parameters to obtain high yield. For each of the feedstock, the biodiesel yield increased with increase in NaOH concentration. The highest yield was obtained with 1% NaOH concentration for all. The effect of methanol in the range of 4:1–8:1 (molar ratio) was investigated, keeping other process parameters fixed. Optimum ratios of palm kernel oil and coconut oil biodiesels yielded 98% each at methanol: oil molar ratio of 8:1. The physiochemical properties obtained for each methyl showed superior properties compared with those reported in published data.
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1. Introduction

Biodiesel produced from vegetable oil has been long known as a viable alternative to petroleum diesel. It is known to be biodegradable, renewable, produce lesser emissions, nontoxic and free from sulphur. Rudolf Diesel (1858–1913), credited with the invention of diesel engine originally used peanut oil as fuel. Over 100 other feedstocks have since been discovered for the production of biodiesel. The choice of feedstock adapted by a country depends on availability, cost and whether it is edible or not. Argentina prefers to use soybean oil contrary to china who has a high demand for soybean for preparation of Chinese food [1]. However edible palm oil is preferred in Asian countries since they have surplus in production while rapeseed oil is preferred in Europe. Other countries such as Ghana are struggling to choose their preferred feedstock since there is not enough of any of the oils whether edible or not.

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Biodiesel is the only and first commercial scale fuel to have met America's EPA definition as an advanced biofuel, since it reduces greenhouse gas emissions by more than 50% compared with petroleum diesel. However, in spite of numerous advances in biodiesel production technology no major Original Equipment Manufacturer (OEM) gives warranty for the use of B100 (100% biodiesel). Use of B20 (20% biodiesel blended with 80% petroleum diesel) or below does not void warranties for 90% of the medium and heavy duty truck vehicles. This position of the OEM is because no biodiesel is the same. Even physiochemical properties of biodiesel from the same feedstock may differ depending on the species, mode of oil preparation, water content, type or concentration of catalyst, molar ratio of alcohol and even reaction time. The quality of feedstock is not guaranteed. This is why in order to protect consumers from unwittingly purchasing substandard fuel, OEMs have stated formally that the biodiesel must meet ASTM D-6751 (American society for testing and materials) [2,3] and/or EN14214 (European committee for standardization).

Appropriate feedstock selection and production technology is therefore vital for biodiesel production [4]. Feedstock such as coconut oil and palm kernel oil has not been properly investigated for biodiesel production in terms of production technology. Some have studied high physicochemical properties of coconut oil focusing on temperature and pressure neglecting physiochemical properties [5]. Others studied in situ (Trans) esterification of coconut oil using mixtures of methanol and tetrahydrofuran but did not consider yield or catalyst concentration [6]. Catalyst (KOH) concentration and methanol to oil ratio have been investigated for the production of coconut oil but their combined effect on yield has been neglected and base catalysed (Trans) esterification has not been considered [7]. Ethanolysis of coconut oil to produce biodiesel has been done but the effect of methanol, catalyst concentration and their effect on coconut biodiesel yield has not been specified [8].

Though prevalent in West Africa, not much work has also been done on palm kernel oil (B100) as biodiesel [PKOME]. Studies carried out on PKOME considered KOH and not NaOH as base catalyst [9,10]. While characterisation in the literature have not included cetane number and calorific value [10] and neither are the species from which the oil was obtained mentioned, there are many species of palm oil from which palm kernel oil can be produced. These species include *Elaeis oleifera* commonly called American oil palm, *Elaeis guineensis* also called the African oil palm and *Butia capitata* also called Jelly palm usually grown in the Argentina, Brazil and Uruguay.

This research investigates the effect of process parameters including methanol:oil ratio, NaOH base catalyst concentration on coconut, palm kernel and Jatropha biodiesel yield. The influence of sulphuric acid (H_2SO_4) on viscosity is also investigated for the three feedstocks.

2. Materials and methods

2.1. Materials

(Trans) esterification of vegetable oil to biodiesel was carried out in a laboratory scale experiment. The materials used include

1. Flat bottom reaction flask (250 ml) with three necks to contain the oil.
2. Scilogex MS-H-S Magnetic stirrer with hot plate was used. It had two separate regulators for regulating heat and stirring rate respectively.
3. Electronic Beam Balance with 200 g min. and 6000 g max. $e = 10$ d, $d = 1$ g was used to take weight of oils before and after (trans) esterification.
4. Reaction ingredients for the (Trans) esterification include 99.8% methanol, NaOH, 98% sulphuric acid.
5. Other instruments used include
   a. Separating funnel.
   b. 8000 ml beaker.
   c. Spatula.
   d. Filter paper.
   e. Graduated eye dropper.
   f. Graduated syringe.
   g. Pipette.

2.2. Experimental procedure

Acid-catalysed (Trans) esterification requires a much longer time than alkali-catalysed Trans esterification (4). This is why base-catalysed (Trans) esterification is used in this work. A Two-step process was used in the production of coconut oil biodiesel. An alkaline-catalysed esterification using NaOH to convert FFAs in coconut oil to methyl esters to reduce FFA was carried out for an hour. In the second step acid-catalysed Trans esterification was carried out where the pre-treated oil was then converted to methyl ester to further reduce FFA and hence the viscosity.

Both esterification and (Trans) esterification were conducted in a laboratory-scale experiment. The raw coconut oil (200 g) was preheated for an hour to ensure removal of water as a precaution of the oil probably not being well prepared. The preheating was terminated when visual inspection showed that there were no more bubbles. For all test runs for the variations, temperature was kept constant and stirring was at same speed. Methanol mixed with NaOH was added to the preheated coconut mixture in the flat bottom reaction flask and stirred for an hour. Test runs for NaOH and H_2SO_4 catalyst concentrations were all done at 0.6, 0.8,1 and 1.2 (w/w). The weight measurement (wt.%) was used instead of (v%) because weight gives a more precise measurement since volume changes once there is evaporation of the liquid. Methanol:oil molar ratio variations were done at 1:4, 1:5, 1:6, 1:7 and 1:8. The mixture was stirred for some time at the same rate and time for all test runs. In the second step H_2SO_4 was added to the pre-treated mixture and quickly stirred for about an hour. The essence of adding H_2SO_4 was to further reduce FFA and hence the viscosity of the biodiesel. Wet washing was then carried out with hot distilled water at 60 °C and then dried to obtain the Coconut oil biodiesel. The same procedure was carried for Palm kernel oil and Jatropha oil.

Each of the procedure mentioned above was repeated for each variation of base catalyst (NaOH), acid catalyst (H_2SO_4) and methanol:oil molar ratio. The effect of base catalyst concentration, acid catalyst concentration and methanol: oil molar ratio on biodiesel yield of coconut, Jatropha and Palm kernel oils was studied. Yield of biodiesel obtained was calculated as

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