Production of Biodiesel From Palm Olein With The Aid Of Methanol And Potassium Hydroxide Catalyst

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Abstract

The rapid growth of industrialisation has resulted in an ever-increasing demand for energy, with fossil fuels being an essential source of fuel for vehicles in the transport sector of countries. The world fossil fuel reserve is fast depleting, and also, it dissipates unhealthy emissions, this, has led to researches to seek sustainable alternatives in biofuels production. The authors experimented with the production of biodiesel from refined, bleached and deodorized palm olein (RBD) extracted from unrefined palm oil (UPO). Despite being considered as a feasible biodiesel feedstock, scanty reports had been found on the processing of biodiesel from palm olein compared to other oils from the palm tree. The transesterification of RBD palm olein with methanol and potassium hydroxide (KOH) as catalyst yielded biodiesel with an average yield greater than 50% in this experimental work. The derived biodiesel has a density of 0.884 g/ml and a flashpoint of 208°C, which is equivalent to ASTM D975 for biodiesel fuels. This result has proven this technique viable and will serve as a reference for continuous research on the biofuel production process.

Keywords: *Palm Olein, Biodiesel, Cleaner energy and Transesterification.*

1. Introduction

The limitations of existing fossil fuels include the depletion of global oil reserves and high carbon emissions (Madyira, Nkomo, & Akinlabi, 2012). The world is rapidly moving towards reducing the carbon footprint (Olatunji et al., 2019), and that is a primary drive behind researches in the field of biodiesel, a notably sustainable clean fuel (Yusuf et al., 2019). Biofuels, as an evolving renewable energy source, has had some considerable interest due to their purported ability to reduce hazardous emissions into the environment during operations, compared with their fossil fuel counterparts (Jabade, Sakthivel, & Chavan, 2020). Biodiesel usage is becoming famous with a lot of researches ongoing to improve on its production and performance indices (Avagyan & Bhaskar Singh, 2019; Parawira, 2010). Biodiesels extracted from palm oil had been noted for being particularly environmentally friendly free of nitrogen or sulphur. The palm olein is a bye product (sometimes referred to as waste) from palm oil production (Zahan & Kano, 2018). Palm fruits have been discovered over 5000 years in South-Eastern Asia, Africa and Latin America (Anyaoha, Sakrabani, Patchigolla, & Mouazen, 2018).

Unlike other oil produced from palm oil, scanty reports of biodiesel production from palm olein had been found published online (Tambun, Gusti, Nasution, & Saptawaldi, 2017). However, palm olein had been referred to as a low-cost biodiesel feedstock (Anguebes-franseschi et al., 2016). Yet, some of the biodiesel experiments carried out with the use of palm olein are here reviewed. Girish (2018) reported a 98% yield of biodiesel from palm olein using a heterogeneous catalyst (Crab shell) (Girish, 2018) while Tambun et al., (2017) used catalytic cracking process (ZSM-5 as a catalyst), obtaining the highest yield of 85% at a 400°C temperature and 120 minutes of reaction time. The methods used in these mentioned works, that is, heterogenous catalyst and catalytic cracking, are not preferred for mass biodiesel production (Abbaszaadeh, Ghobadian, Omidkhah, & Najafi, 2012).

Transesterification technique had been widely accepted as an adequate choice for biodiesel production because of its simplicity and the fact that its product has the most proximate characteristics to that of diesel (Kapadia, Brahmbhatt, Dabhi, & Chourasia, 2019). Anguebes-franseschi et al. (2016) investigated the feasibility of producing biodiesel using a crude palm olein. The authors used a two-step process, that is, acid esterification and alkaline transesterification. The experiment obtained an optimum biodiesel yield of about 90% at 2.5wt% of catalyst, at 64.5° C reaction temperature 150mins of reaction time (Anguebes-franseschi et al., 2016). Pannilawithana et al., (2017) also attempted to produce biodiesel from palm olein using a more environmentally friendly heterogeneous catalyst, that is, calcium diglycerides. The process produced an optimum yield of 92% of biodiesel at 3hours of reaction time and 65°C temperature. The latter reported all of the tested properties of the produced biodiesel to be by ASTM recommendations except kinematic viscosity (Pannilawithana & Pathirana, 2017). Although potassium hydroxide (KOH) has been identified as an excellent catalyst for the production of biodiesel, the authors found no report on its use for such production from palm olein. These formed the basis for this present work.

Oil palm tree produces two kinds of oils: unrefined palm oil (UPO) gotten from the mesocarp and palm kernel oil from within the kernel (Foo & K. Tun Abdul Aziz, 2019). The palm oil is extracted from the ripened mesocarp under pressure. Indonesia, Malaysia, Thailand, Colombia and Nigeria are the leading producers of palm oil in the world (Ishola et al., 2020). It was established that a hectare of oil palm plantation can produce ten times the value of oil that can be gotten from other leading oilseed crops (Lee & Ofori-boateng, 2013). UPO in its natural state, has a brilliant orange colour because of the high level of carotene pigmentation and always remains in a semi-solid state at ambient temperature. In its natural state, it is broadly used in margarine production and vegetable shortenings. When refined, it separates into palm stearine and palm olein (Tan et al., 2010). The palm olein when compared to palm oil has exceptional attributes, which include the ability to remain totally in a liquid state at room temperature, exceptionally heat safe, opposes the arrangement of breakdown products when used for frying and an increment in the timeframe for realistic usability. Palm olein is the most utilised oil used for frying because it is considered to have the highest quality level when compared to others(Mba, Dumont, & Ngadi, 2015).

Generally, the feedstock for biodiesel production via transesterification process is classified into four major groups, namely: vegetable oils, waste cooking oil, waste animal fats and algae. For a region that does not promote the growth of this feedstock's, jatropha curcas serves as a substitute. According to Moser (2009), biodiesel raw materials are tested for desirable characteristics such as availability of the material, high oil content, the good composition of fatty acid and compatibility with existing farm infrastructure (Moser, 2009). Biodiesel is utilised in compression ignition (CI) engines by amalgamation with petrol, or petroleum-derived diesel. To minimize some inadequacies of biodiesel, alcohols like methanol, pentanol, butanol, hexanol and ethanol are incorporated as additional oxygen to reducing associated emissions (Devarajan, Nagappan, & Munuswamy, 2017). The addition of alcohols can be done through fumigation, two- way injection of fuel, biodiesel blending or biodiesel emulsion with alcohol. In trying to provide a solution to the issue of high viscosity associated with fuels gotten from vegetable oil, different methods such as oil dilution, oil pyrolysis (thermal cracking), micro-emulsion and transesterification have been incorporated to significantly reduce viscosity value to the standard range (Chabisha Precious Makgaba, 2017).

Transesterification involves the conversion of the fatty acids chain of triglyceride molecules found in oil samples into ethyl or methyl esters in the presence of an alcohol and catalyst mixture (Carlos, Guerrero-Romero, & Sierra, 2011). According to the American Society for Testing and Materials Standard (ASTMS), the esters mono-alkyl formed are known as Biodiesel. Generally, the efficacy of the conversion of oil to biodiesel employing the transesterification process largely depends on the reaction temperature, reaction time, alcohol to oil ratio and type and quantity of the catalyst used (A.L. Paul Anawe & Adewale, 2018; Gashaw & Getachew, 2015; Chabisha P

Makgaba, Aniokete, & Daramola, 2018). Alcoholysis occurs when alcohol is used for the transesterification process. Alcoholysis involves the switching of the organic R˝ group of an ester with the R' group of alcohol to produce glycerol and fatty acid alcohol ester (Ayhan Demirbas, 2008). The catalyst mixture can be in the form of an alkaline, acidic or enzymes medium (Bello, Oguntuase, Osasona, & Mohammed, 2015). Potassium Hydroxide (KOH) and Sodium Hydroxide (NaOH) are the commonly used soluble base catalyst used for the transesterification process (Girish, 2018). The catalyst mixed with methanol is stirred vivaciously in a reactor before being siphoned into the oil. Continuous mixing continues until a decent transesterification reaction occurs with the appearance of two fluid layers: ester (biodiesel) and unrefined glycerol (Lam, Jamalluddin, & Lee, 2019). Kumar et al. (2017) detailed the transesterification process employing the use of biochar-based catalyst. It is a heterogeneous catalyst, which bears arranged corrosive sulfonic gathering utilising the carbon support of bio-char. The ability of the catalyst to be reused was poor under high temperature/weight conditions (Kumar et al., 2017). Generally, Enzymes lessen the activation energy for the various biochemical reaction (Sarin, 2012). A typical transesterification process was represented in figure 1. The alkyl ester and glycerol are products of the esterification reaction in subsequent stepwise reactions.

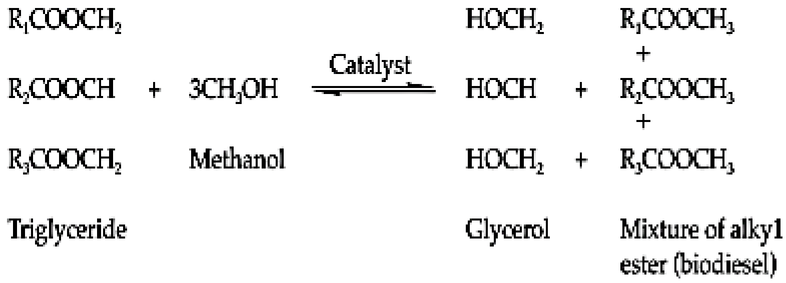

Figure 1: Transesterification Reaction Equation (Jabade et al., 2020)

2. METHODOLOGY

2.1 Biodiesel Production

2.1.1 Transesterification Procedure

200ml of the palm olein oil was weighed into a conical flask, which was placed on a magnetic stirrer regulated to a temperature between 600C to 650C. A methoxide solution containing 1.5g of KOH and 20%wt of the volume of methanol was added into the oil. A reflux condenser was also set up to prevent the escape of the methoxide solution while the reaction was stirred at revolution per minute (rpm) of 5 for I hour, 30 minutes. After separation for 24 hours in a separating funnel, two layers were formed, a darker coloured layer at the bottom (glycerol) and a layer of trans-esterified oil (biodiesel) at the top. The bottom layer was also disposed of as waste. Figure 2 shows a schematic representation of the transesterification process while figure 3 shows the step by step process

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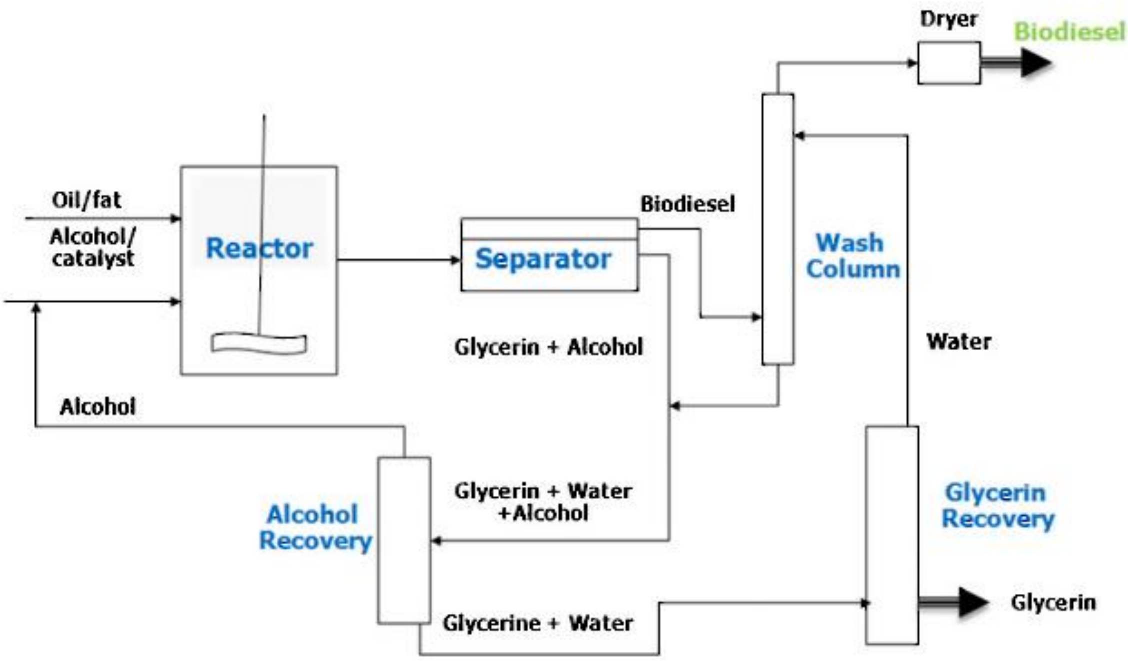

Figure 2: Flow chart of a typical Transesterification Process (Abbaszaadeh et al., 2012)

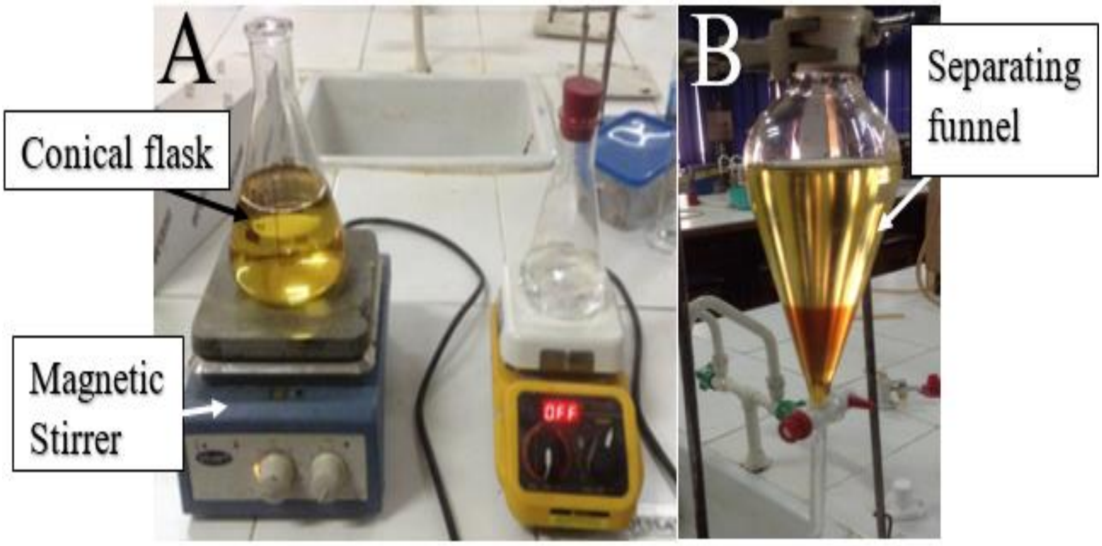

Figure 1: (A)-Oil Heating in Conical Flask and Mixture of Methanol and KOH. (B)-Separation of Product into Crude Biodiesel and Glycerol

2.1.2 Biodiesel Washing and Heating Procedure

The biodiesel product has to be washed in other to remove every form of glycerin and impurities. The washing procedure involves boiled water added to the biodiesel and allowed to settle in a separating funnel for 12 hours. The bottom layer is continuously removed until a transparent sample is achieved. The cleared biodiesel is emptied into a beaker and allowed to heat to a temperature of 550C to remove water content.

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2.2 Measurement of Parameters

2.2.1 Density

The density of biodiesel, measured in kg/m3, was determined with the density bottle. The 50 ml empty specific density measuring bottle, and the lid was first measured with a scale. The specific density bottle was filled to the brim with biodiesel and then covered, leaving some of the biodiesel sipping through the lid. The relative density bottle was weighed and recorded with biodiesel.

The oil's density was then mathematically calculated with equation 1

$$Density(g/ml) = \frac{m_2 - m_1}{v} \quad (1)$$

Where:
m_1 = mass of empty specific gravity bottle with the lid on it (kg)
m_2 = mass of specific gravity bottle filled with the oil (kg)
v = volumetric capacity of the bottle for specific gravity which is 50ml

2.2.2 Flashpoint

The flashpoint of a substance is defined as the minimum temperature at which the material ignites when heated up. The flashpoint of biodiesel was determined with the flashpoint tester in a vacuum. While the gas supply valve of the gas cylinder was open, the biodiesel was poured into the cup of the flashpoint. The temperature at which inflammation was observed was recorded as a flashpoint.

2.2.3 Viscosity

Viscosity is defined as a measure of the flow resistance of a fluid. This was measured to examine the differential behaviour of the ambient temperature and the biodiesel sample prepared at room temperature. This was done with the OFITE viscometer.

2.2.4 Cetane Number

The cetane number is an assessment of the quality of ignition and combustion of a fuel type. Cetane was obtained by averaging the results of 5 combustion curves. The biodiesel of palm olein was injected to fill a constant volume combustion chamber of a hand-held Labgent octane/octane gauge, where it was compressed and ignited.

3. Result and Discussion

3.1 Biodiesel Production

Table 1 presents the results obtained from the nine batches of transesterification experiments using methanol as alcohol. While table 2 shows the conformity of the produced palm olein biodiesel to the ASTM specifications.

Table 1: Transesterification Characteristics and Result Utilizing Methanol

Experimental conditions	**Transesterification**								
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9
KOH quantity (g)	0.75	0.7	1.5	1.5	1.5	3.0	3.0	3.0	3.0
Reaction temperature (℃)	65	65	65	65	65	65	65	65	65
Reaction time (minutes)	90	90	90	90	90	90	90	90	90
Palm olein quantity (ml)	100	100	200	200	200	400	400	400	400
Methanol quantity (ml)	20	20	40	40	40	80	80	80	80
Quantity of biodiesel obtained (ml)	75	75	150	150	150	300	300	300	300
Quantity of by product obtained (ml)	45	45	90	90	90	180	180	180	180
Biodiesel yield (%)	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5	62.5

Table 2: Properties of the Feedstock and the Biodiesel Obtained in Comparison with ASTM Standard

	Palm olein oil	**Palm-Olein Biodiesel**	**ASTM standard**
Density	922 kg/m³	884 kg/m³	-
Flash point	323.9 ℃	208 ℃	52 ℃(min)
Cetane Number	-	48.91	47 (min)
Kinematic Viscosity	-	4.56	1.9 – 6.0
Flash Point	-	208	130 (min)
% Yield	-	62.5	

3. Conclusion

The aim of this research, which was to ascertain the feasibility of producing biodiesel from palm olein, was met. The percentage yield of biodiesel using methanol in the presence of Potassium Hydroxide (KOH) catalyst was above average (50%), which confirms its feasibility for mass production. The biodiesel derived has a density of 0.884g/ml and a flashpoint of 208 ℃, which confirms with that of ASTM D975- Standard Specification for diesel fuels. This research has proven this technique viable and will be useful as a reference for future work on optimisation biofuel production process from palm olein.

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