EFFECTS OF HYGROSCOPIC POTASH LYE CATALYST CONCENTRATION ON THE WASTE CHICKEN FAT METHYL ESTER PRODUCTION

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ABSTRACT

The work presented in this study demonstrates the effect of the hygroscopic potash lye catalyst concentration on the waste chicken fat methyl ester production. The aim of this paper is to determine the effect of temperature, catalyst ratio and methanol ratio on fatty acid methyl ester (FAME) yield from waste chicken fat (WCF). The finding shows the optimum yield were 95.4 % with 0.006 w/w hygroscopic potash lye catalyst and 0.3 w/w methanol at 50°C. The final analysis of this study identifies the FAME density was 873.4 kg/m^3, the iodine value, 117 g I/100 g and the acid value, 0.561 mg KOH/g. Moreover, the compositions of fatty acids were 0.22 % of methyl laurate ($C_{13}H_{26}O_2$), 19.98 % of methyl palmitate, ($C_{17}H_{34}O_2$), 41.08 % of methyl stearate ($C_{19}H_{38}O_2$) and 0.17 % of methyl linoleate ($C_{19}H_{34}O_2$) henceforth this FAME produced exhibit properties very similar to ASTM D6751 and EN 14214. This study confirms that the FAME transesterified from waste animal fats with the hygroscopic potash lye catalyst could be a potential alternative to petrodiesel.

KEYWORDS: *Biodiesel; waste chicken fats; hygroscopic potash lye catalyst.*

1.0 INTRODUCTION

In recent years, alternative lipids as oil residues in waste frying cooking oil and inedible waste animal fats have gained considerable attention from green fuel sector. Today's energy system is unsustainable because of equity issues and technology competition as well as economic, political and environmental concern that have implications far into the future. Consequently, residues were used in a recycle program to take advantage of these low cost and low quality resources enabling integration of the sustainable energy supply and waste management in food processing facilities. In this situation, there is a need to find ways to convert the waste into biofuel. Related to this trend, biodiesel is an alternative fuel consists of fatty acid methyl esters (FAME) produced by transesterification of triglycerides with methanol. It is produced by chemically reacting

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the oil or ester with an alcohol in the presence of a base or acid catalyst. The products of this reaction are the monoesters, known as biodiesel; and the alcohol named glycerin, which is a high value byproduct for renewable fuel production. For instance, waste chicken fat (WCF) have a great potential as feedstocks for biofuel industry because they are not commodities, hence having a lower market value and almost zero cost.

Cetane number is an important parameter to the evaluation of the self-ignitability of fuel. Normally, the cetane number of diesel fuel is from 45 to 60 (Ruina et al., 2014). Darunde (2012) claimed that the saturated fatty acids from WCF are the source of high cetane number (CN). Biodiesel of animal origin has positive properties such as large values of heating value (HV) and CN. In general the HV and CN of petroleum-based diesel fuel range between 40 and 44. The higher the cetane number, the more efficient the fuel. Animal fat biodiesel has a higher CN than plant oil biodiesel because of its oxygen content. Better combustion is achieved as a result of less ignition delay time or higher CN (Mustafa and Havva, 2010). The WCF with a higher CN will indicate a shorter ignition delay time, more complete combustion of the fuel and hence should improve the fuel efficiency.

In addition, the WCF FAME able to present a number of environmental, economic and social advantages. Biodiesel and conventional diesel properties are very similar; however biodiesel has higher CN than conventional diesel, virtually no sulfur and no aromatics and high flash point. Due to the near absence of sulfur in the WCF, it helps to reduce the problem of acid rain caused by emission of pollutant from fuels burning. The lack of aromatic hydrocarbon (benzene, toluene, etc.) in biodiesel reduces unregulated emissions as well as ketone and benzene. In relation to that, breathing particulate matter has been found to be hazardous for human health, especially in respiratory system. This might due to its content that comprising of elemental carbon (~31 %), sulfates and moisture (~14 %), unburnt fuel (~7 %), unburnt lubricating oil (~40 %) and traces of other substances (Idris, 2016).

Due to the scarcity of fossil fuels and increase of population, there is an urgent need for renewable energy sources that can replace petrodiesel. This study focuses on investigating the effect of the hygroscopic potash lye catalyst concentration (wt.%) that represents the catalytic acitvity on the WCF FAME transesterification. The current findings add to a growing body of work such as the effect of the reaction parameters, for examples catalyst dosage, molar ratios, and the reaction temperature. As a result, these biodeiesel specifications research findings were compared with the specifications in EN 14214 standard and ASTM D6751 for biodiesel.

2.0 METHODOLOGY

Common vegetable oil and animal fats are esters of saturated and unsaturated monocarboxylic acids with trihydric alcohol glyceride. These esters are known as triglyceride which react with alcohol in the presence of catalyst. This reaction is known as transesterification (José et. al, 2016). Figure 1 shows the transesterification reaction whereby the R_1, R_2 and R_3 are long chain hydrocarbons or also known as fatty acids.

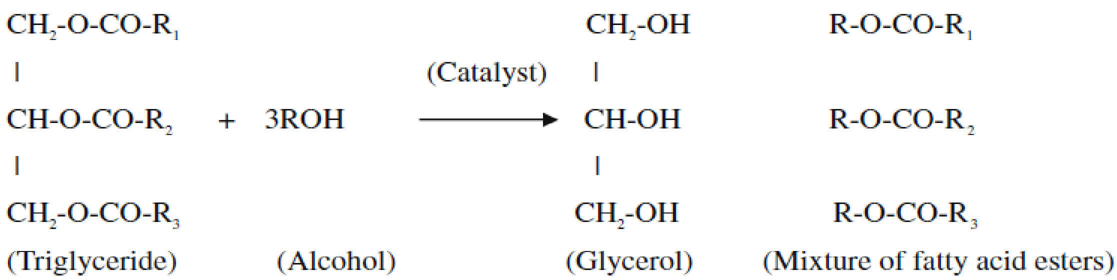

Figure 1. Transesterification reaction

Biodiesel, chemically known as FAME, is a biodegradable and environmentally benign nonpetroleum-based fuel. Bhatti et. al. (2008) also stated that there are normally five types of chains in vegetable oil and animal fat which are palmitic, stearic, oleic, linoleic and linolenic. Vegetable oil and animal fats may consist of small amount of water and FFA. The hygroscopic potash lye catalyst refers to the strong base catalyst, generally consumed, potassium hydroxide (KOH). In the hygroscopic potash lye-catalyzed FAME transesterification, the base catalyst will react with the FFA to form the byproduct, soap and water. This process is known as saponification. Several studies (Agarwal, 2007: Demirbas, 2008) have discovered that the saponification reaction is undesirable because the soap lowers the FAME yield and obstructs the separation of the esters from the glycerol. Consequently, the soap formation can increase the catalyst concentration hence the process will involve a higher cost. In the hygroscopic potash lye-catalyzed transesterification, the catalyst activity declines due to side reactions. The key problem with this explanation is the absence of chain transfer and rupture reactions of the catalyst.

2.1 Acid Esterification as FFA Pretreatment

Michelle and Angelo (2016) concluded that acid esterification is the most promising high FFA concentration pretreatment of the extracted oil in WCF. The FFA will be converted to FAME by direct acid esterification and henceforward the water needs to be removed. At the end of the esterification reaction, the acid catalyst has to be neutralized in order to isolate the product. This finding, while preliminary, suggests that the FFA conversion rate of 80 % was set as a cutoff point to evaluate the effectiveness of the esterification reaction. The FFA conversion rate was examined by Equation (1).

$$\text{FFA Conversion (\%)} = \frac{(Initial\ FFA - Final\ FFA)}{Initial\ FFA} \times 100\ \% \qquad (1)$$

where initial FFA is the initial acid value (mg KOH/g) and final FFA represents the final acid value (mg KOH/g).

The current investigation was limited by three different factors which are the reaction temperature, the methanol to oil ratio and the hygroscopic potash lye catalyst to oil ratio. The experiment was conducted at three different temperatures, 50°C, 60°C and 70°C. As for the hygroscopic potash lye catalyst to oil ratio, the values are 0.006 w/w, 0.008 w/w, 0.01 w/w and 0.012 w/w. There are four different methanol to oil ratios established in this study which are 0.1 w/w, 0.2 w/w, 0.3 w/w and 0.4 w/w with 50 g of waste chicken fat per batch. The reaction time was kept constant throughout the experiment which was one hour.

3.0 RESULTS AND DISCUSSION

3.1 Effect of Reaction Temperature to FAME

The rate of reaction is influenced by the reaction temperature as per kinetics of reaction. The maximum yield of FAME was observed at temperature ranging from (50 ± 5)°C. Further increase in temperature has negative effect on the conversion. Transesterification can occur at different temperatures and thereupon the temperature meaningfully affects the reaction rate and the percentage yield of FAME. According to Figure 2, the highest percentage yield is at low reaction temperature, 50°C instead of 60°C and 70°C.

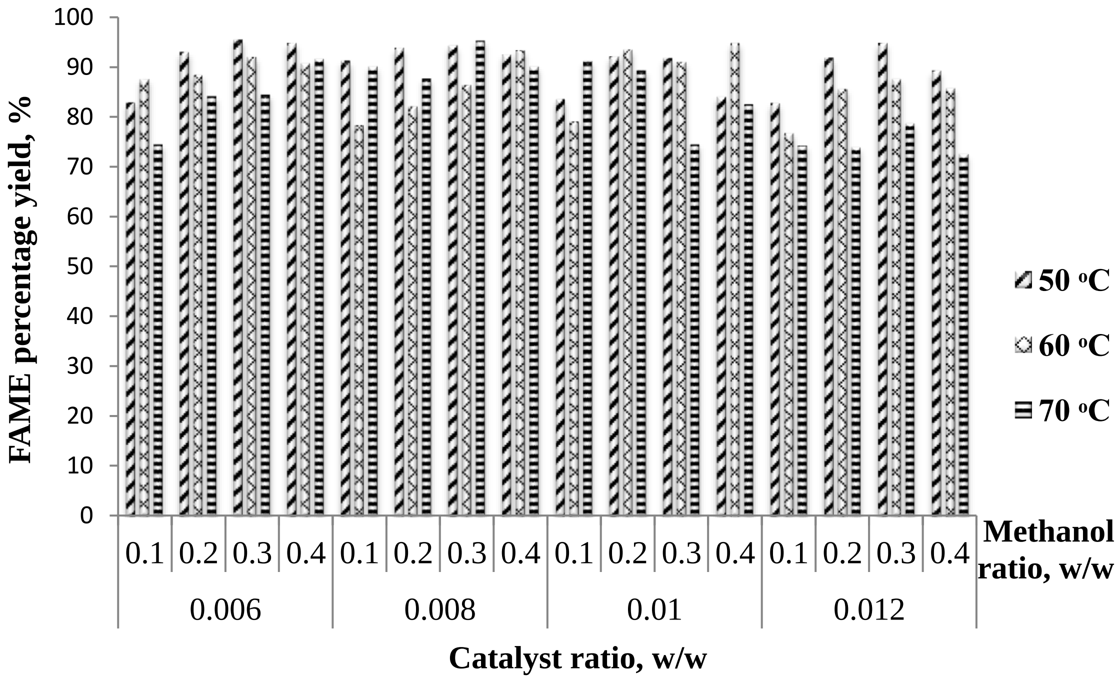

Figure 2. FAME percentage yield vs catalyst ratio

3.2 Effect of Methanol Ratio to FAME

The most striking result emerged from the data is that the optimum methanol ratio for transesterification is at 0.3 w/w significantly yield the highest biodiesel up to 95.4 %. Based on Figure 2 above, the current study found that the higher methanol ratio, the lower the FAME yield. According to Abdelrahman et al. (2016), with higher methanol amount, the FFA conversion increased but the yield decreased. This is due to the reversible transesterification reaction as the additional methanol accelerate considerably with an adjustment of the new equilibrium. A high amount of methanol interferes the separation of glycerol due to an increase in solubility while the remaining glycerol remaining in the solution drives the reaction equilibrium again, resulting in the lower yield of biodiesel. Therefore, it can be concluded that the higher the amount of the methanol used, the lower the biodiesel yield. Similar trend on the effect of methanol ratio to biodiesel yield was found by Komintarachat and Chuepeng (2010) in their studies. According to Idris (2016), higher molar ratio of alcohol to oil interferes in the separation of glycerol. On the other, hand with lower molar ratio, more reaction time is required and conversion increases but recovery decreases while the optimum alcohol ratio also depends on the type and quality of oil.

3.3 Effect of Catalyst Ratio to FAME

The effect of hygroscopic potash lye catalyst loading (wt.%) on FAME yield was also studied. A catalyst functions to accelerate the reaction rate. The catalyst is an important factor in transesterification of waste chicken fat into biodiesel. The catalysts that are commonly used is sodium hydroxide (NaOH). In this study, the base catalyst used was hygroscopic potash lye catalyst with similar name, KOH. Figure 2 shows the results of preliminary analysis that with more catalyst loading, the more yield is obtained. There was a significant positive correlation, with higher methanol amount - the FFA conversion increased but the yield decreased. The present findings seem to be consistent with other research found in Komintarachat and Chuepeng (2010). The transesterification reaction is reversible and any additional methanol would accelerate considerably the adjustment to a new equilibrium. A high amount of methanol interferes with the separation of glycerol due to an increase in solubility while the glycerol remaining in the solution drives the reaction equilibrium back, resulting in the lower yield of biodiesel.

3.4 FAME Analysis

The composition of biodiesel was determined using gas chromatography (GC) with retention time at 20 minutes. There are four fatty acids in the biodiesel identified namely methyl laurate, methyl palmitate, and methyl stearate and methyl linoleate. The FAME has the following composition: 0.22% of methyl laurate ($C_{13}H_{26}O_2$), 19.98 % of methyl palmitate, ($C_{17}H_{34}O_2$), 41.08 % of methyl stearate ($C_{19}H_{38}O_2$) and 0.17 % of methyl linoleate ($C_{19}H_{34}O_2$).

Table 1. Biodiesel properties comparison

Characteristic	Experimental Value	EN 14214	ASTM D6751
Density, kg/m^3	873.4	860-900	860-900
Acid Value, mg KOH/g	0.561	< 0.5	< 0.8
Iodine Value g I/100g	117.0	< 120	< 120

4.0 CONCLUSION

The empirical findings in this study shows that the optimum parameters for producing biodiesel in this project is at 50°C with the ratio of hygroscopic potash lye catalyst to oil 0.006 w/w and methanol to oil ratio of 0.3 w/w. The yield obtained at this parameter is 47.7 g of biodiesel and the percentage of yield is 95.4 %. The organic compounds in the biodiesel produced consist of several fatty acids namely methyl laurate, methyl palmitate, methyl stearate and methyl linoleate. The iodine value of the biodiesel produced is 117g I/100 g while the density obtained is 873.4 kg/m^3 and the Acid Value of 0.561 mg KOH/g meets the ASTM D6751 and EN 14214.

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