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Study of the temperature to render fat down affecting the biodiesel yield from cow fat by the transesterification reaction method

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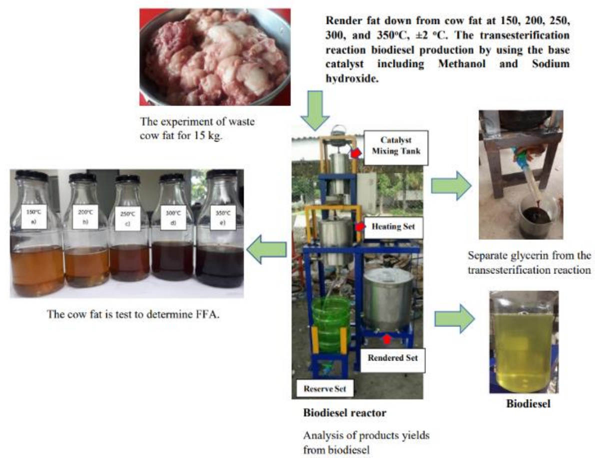
Abstract

Animal fats are high in saturated fatty acids, so they are useful in the part of soap making, including biodiesel oils. Its advantage is high heating and low cost. The aim of this research was to study the temperatures to render fat down from cow fat at 150 °C, 200 °C, 250 °C, 300 °C, and 350 °C, ±2 °C affecting the biodiesel oil yield. The transesterification reaction biodiesel production by using the base catalyst including Methanol (CH_3OH) and Sodium hydroxide (NaOH). The reaction temperature was controlled at 50 °C. The experiment is carried out with a biodiesel reactor consisting of the rendered set, catalyst mixing tank, and heating set to get rid of water from biodiesel. The trend toward the increased temperature to render fat down also affected the higher FFA and a temperature of 350 °C, this resulted in a higher range of 2.53% of the FFA. The result was found that the optimum temperature for rendering fat down was 250 °C and the biodiesel oil yield was 75.50% by volume, the HHV had a maximum of 41.17 MJ kg^{-1}, and viscosity of 4.60 cSt. Furthermore, it illustrated that the temperature to render fat down that is too high will affect to decrease the biodiesel yield but increase glycerin content.



Keywords: Biodiesel; Transesterification; Cow fat; Render fat down

Introduction

The downward trend in fuel is due to the increase in consumption. One of the most important elements that affects the world economy and politics is the sustainability of petroleum resources; as such, one alternative energy is biodiesel. The main advantages of this type of fuel are it is non-toxic and biodegradable. In addition, it can be used directly with an engine without the need for any modification [1 – 3]. There are four types of biodiesel processes, which are biodiesel for direct use and blending, microemulsions, thermal cracking or pyrolysis, and transesterification [4 – 6]. The transesterification process is the most popular technique for biodiesel production because it contains the parent oil or fat with an alcohol, usually methanol, in the presence of a catalyst, usually a strong base such as sodium or potassium hydroxide [7]. Biodiesel may also be produced from less expensive fats, including inedible tallow, pork lard, and yellow grease. These raw materials can be suitable for biodiesel production. Besides, their high cetane number and heating values are close to the diesel fuel [8]. Although considerable research has been done on animal fat as diesel fuel, in beef tallow, the saturated fatty acid component accounts for almost 50% of the total fatty acids' effective properties of a high melting point and high viscosity [9]. In addition, some studies have investigated the resource availability, energetic efficiency, and inedible beef tallow into biodiesel [10]. Free fatty acids in the oils or fats could also be converted into alkyl esters with an acid catalyst. This could be followed by a standard alkali-catalyzed transesterification to convert the triglycerides [11]. Moreover, free fatty acid (FFA) and water contents have had significant effects on the transesterification of glycerides with alcohol using alkaline or acid catalysts.

Therefore, the FFA level in the oil should be below a desired level (ranging from less than 0.50% to less than 3%) for alkaline transesterification to take place. Likewise, the FFA content after acid esterification should be minimal or otherwise less than 2% of FFA [12, 13]. Otherwise, it compromises the catalyst's reaction competency, resulting in an incomplete reaction process, impure biodiesel, or soap yield instead of biodiesel [19]. Besides these aspects, other issues would need to be considered.

Among the different non-edible animal fats beef tallow, pork lard, chicken fat, and grease can be used to produce biodiesel. However, because animal fats have a significant content of saturated fatty acids, the produced biofuel presents a higher cloud point [21, 22]. Beef tallow is a waste product from rendering operations. Several studies report the potential of extracting biodiesel from beef tallow. The chromatographic analysis showed that biodiesel from beef tallow has more saturated esters which means it has a poor low-temperature characteristics and removing the saturated fatty acid [23]. This led to the melting of beef tallow was rendered into smaller pieces and placed in a pan which was heated to a temperature of 400 °C for 10 min [24]. Fat rendering was accomplished using boiling water, microwave-assisted, and acetone extraction at reflux temperature [25]. Optimal effective heating, process conditions are required to produce high biodiesel yields [26]. The temperature also affected the saturated fatty acid content [17]. Many researchers have conducted studies to resolve all the problems of biodiesel catalyst, feedstock types, reaction temperature, and stirring. Hence, each parameter has been found to be equally important to achieve high-quality biodiesel.

Accordingly, this paper had the objective to study the temperature to render fat from cow fat by the transesterification reaction method and using the base catalyst, including methanol (CH_3OH) and sodium hydroxide (NaOH). This found the optimum temperature for rendering the fat, compared the appropriate temperature for rendering, determined the FFA of the rendered oil sample at every temperature, and tested the initial properties of the fuel.

Materials and Methods

The waste cow's research process (Fig. 1) was processed through the heating process at the set temperature, called feedstock. When the rending fat down process was conducted before the transesterification, the FFA must be examined. After the process, the soap was obtained, and the FFA must be rechecked. The next step after securing biodiesel was the purification process. In the production of biodiesel from cow fat, experiments were carried out from the biodiesel reactor. This consisted of a catalyst mixing tank, which was a tank for mixing catalysts, which were Methanol (CH_3OH) and Sodium hydroxide (NaOH), rendered set to render the fat down from the waste cow to get the feedstock and change the render temperature, heating set that was a tank for washing crude biodiesel and provided the heat to get rid of water from the product, and reserve set that helped to cool down crude biodiesel at the room temperature (Fig. 2), which could be combined together to be one machine. This studied the optimal temperature to render the fat used on the created machine, thus providing the best percentage of the product yield.

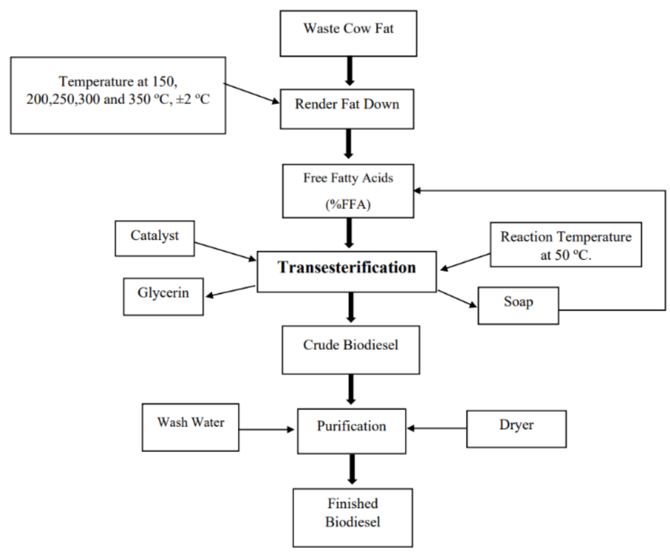


Fig. 1 Research Process.

Cow fat as biodiesel feedstock

To prepare the waste cow fat beforehand in the rendered set required a modestly small piece that weighed 15 kg per experiment. The rendered set comprised a flask equipped with a magnetic heater and digital thermometer, which had a stirring speed of 20 rpm and was conducted for 40 min . The temperatures to render fat down were 150 °C, 200 °C, 250 °C, 300 °C, and 350 °C, ±2 °C respectively (Fig. 3). Then, the waxy materials and other suspended matter and residue from the melted fats were then filtered. The experiment used cow fat oil at an equal temperature of 50 °C and 10 L per experiment. The reaction mixture was heated for specified period of time, cooled and distilled to remove excess methanol [14]. These free fatty acids are readily reacted in the presence of an alkali and important factor that will cause “Yale” in the production of biodiesel. The FFA content was the key parameter for determining the viability of the base-catalyzed transesterification process. Therefore, the value of the FFA of every feedstock was tested from all the render fat down temperatures [19]. Determination of the FFA in cow fats is done by potentiometric titration in Ethanol / Diethyl ether as solvent with NaOH in isopropyl alcohol [20].

Fig. 2 Biodiesel reactor.

Transesterification

Among the four techniques, the chemical conversion (transesterification) of the oil to its corresponding fatty ester was the most promising solution for the high viscosity problem [8]. The transesterification process required the preparation of a solution. Moreover, the optimum conditions for the base-catalyzed transesterification of cow fat was as follows : 0.50 wt.% of NaOH, molar ratio of methanol to cow fat at 6:1, and reaction temperature at 50 °C [14, 17]. Next, the solution was prepared, which is called base-catalyzed. This comprised a mixture of methanol (CH_3OH) and caustic soda (NaOH) that was placed in the catalyst mixing set, which was stirred at 10 rpm for 30 min. The catalyst mixing tank valve was opened to release the prepared catalyst into the cow fat in the rendered set, which was stirred at 20 rpm for 1 h [14]. When the catalyst was completely combined with the melted cow fat, then the rendered tank valve was opened to release the biodiesel to the reserve set. The mixture was then allowed to cool to room temperature for 12 h. After transesterification, this resulted in crude biodiesel. The products were a mixture of esters, glycerol, alcohol, and catalyst [9]. So that the glycerin and crude biodiesel products would be separated, they were isolated by opening the reserve valve that was between the glycerin and below the tank of the crude biodiesel (Fig. 4).

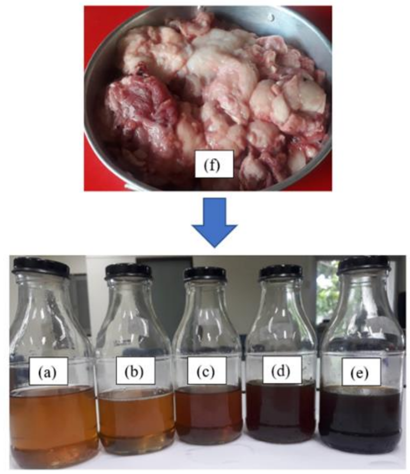


Fig. 3 Cow fat as feedstock (a) 150 °C , (b) 200 °C , (c) 250 °C , (d) 300 °C , (e) 350 °C and (f) waste cow fat.

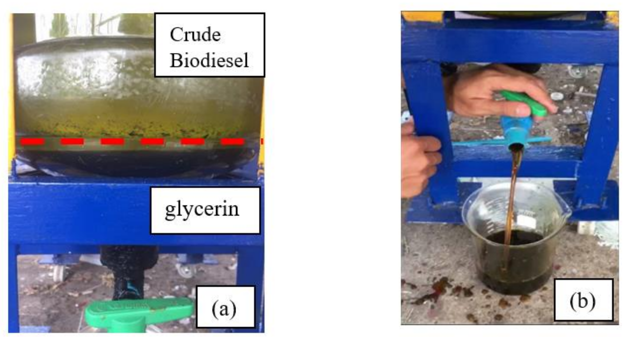


Fig. 4 (a) Stratification occurred in the reserve tank. The top was crude biodiesel and the bottom was and glycerin (b) Open the valve for separating the glycerin and crude biodiesel.

Table 1 Analysis of the biodiesel properties.

Analysis	Standard	Instrument
Heating Value (MJ.kg^{-1})	ASTM D240	Torino Bomb Calorimeter
Viscosity at 40 °C (cSt.)	ASTM D445	Kinematics Viscosity
Flash point – Fire point (°C)	ASTM D93	Flash point – Fire point Set
Free fatty acids	–	Free fatty acids method

Purification of the final product

After the transesterification of triglycerides, the products were a mixture of esters, glycerol, alcohol, catalyst, and monoglycerides. Although glycerin was separated from crude biodiesel, the process's contamination could cause the machines to wear out [9]. Therefore, the crude biodiesel was purified by washing with distilled water 1:1 in the heating set, which was stirred at 20 rpm at room temperature for 30 min. The mixture was then allowed to cool at room temperature for 2 h. As a result, the water and oil could be separated. The moisture content was then removed by heating the oil in an oven for 1 h at a temperature of 110 °C [15]. Following this, the process was completed, and the biodiesel oil was analyzed for its properties according to the benchmark standard as shown in Table 1. The yield of biodiesel was calculated as eq. (1) [13]:

$$\text{Product yield} = \frac{\text{Wt.of product}}{\text{Wt.of raw oil}} \qquad (1)$$

Results and Discussions

Render fat down affecting the feedstock product

The results of the temperature of the render fat down trial lasted 40 min. At low temperatures of 150 °C, 200 °C, and 250 °C, respectively, cow fat could be partially dissolved. Fig. 5 shows the melted cow fat product at 69.67 wt.%, 72 wt.%, and 75 wt.%, respectively. There were also a lot of waxy materials and other suspended matter; however, it melted well to be 96.67 wt.% and 97.10 wt.% at high temperatures of 300 °C, 350 °C, respectively. Thus, there was very little wasted cow fat after the render fat down that was dark brown and very viscous, which the melted cow fat was called feedstock and FFA checks.

The amount of FFAs was important for alkaline transesterification, the FFA level in the oil should be below a desired level (ranging from less than 0.50% to less than 3%) [13]. From Fig. 6, the trend toward the increased temperature to render fat down also affected the higher FFA. As a consequence, the resulting soaps could induce an increase in viscosity, formation of the gels, and made the separation of glycerol difficult [8]. The temperatures at 150 °C, 200 °C, 250 °C, and 300 °C, respectively still resulted in the FFA having low range values of less than 1.50%. On the other hand, at a temperature of 350 °C, this resulted in a higher range of 2.53% of the FFA, and the major problem associated with processing low-cost fats and oils was that they had high quantities of FFAs that could not be easily transformed into biodiesel fuel by conventional alkali-catalyzed transesterification [18].

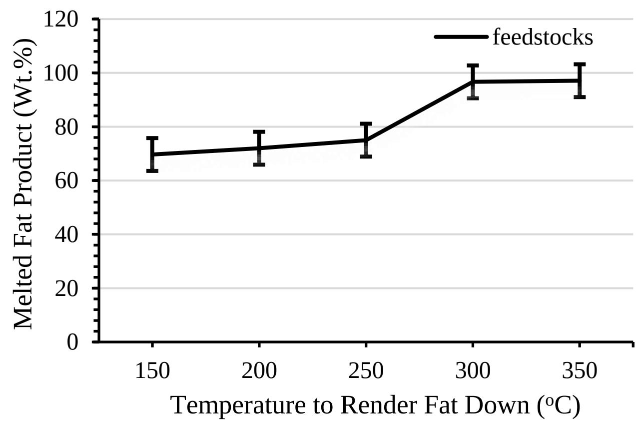


Fig. 5 Feedstock after the render fat down.

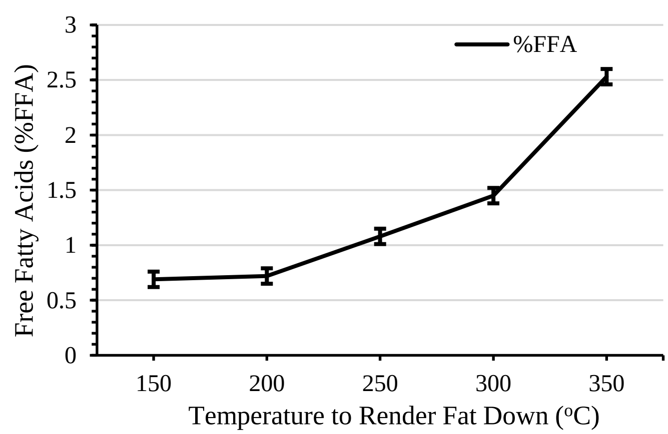


Fig. 6 The relation of the free fatty acids to the temperature.

Table 2 Properties of biodiesel.

Analysis	Temperature to Render Fat Down (°C)				
	150	200	250	300	350
Heating Value ($MJ.kg^{-1}$)	37.94	37.98	41.17	39.96	38.58
Viscosity at 40 °C (cSt.)	5.80	5.20	4.60	4.50	4.50
Flash point (°C)	157	156	152	153	151
Fire point (°C)	165	164	163	161	163

Product yields and fuel properties

Biodiesel, chemically is fatty acid methyl ester if alcohol is used during transesterification [12], 10 L of feedstock, and temperature to render fat down at 150 °C, 200 °C, 250 °C, 300 °C, and 350 °C, respectively with a base type catalyst and purification. As shown in Fig. 7, the relationship of the temperature to the experimental product yields was analyzed. Hence, it was found that the relationship between the temperature to render fat down to glycerin was directly correlated. At the time, the temperature was higher as the amount of glycerin yields increased. The physical and chemical properties of the tallow and fractionates (liquid and solid) at both temperatures were determined. Furthermore, the crystallization temperature influenced the iodine values, FFA values, and the fatty acid compositions of the tallow and fractionates were stearic acid [16]. On the other hand, the temperatures of 150 °C, 200 °C, and 250 °C that received the product yields of both the crude biodiesel and biodiesel were rather high and more than at 300 °C and 350 °C, which in most cases was glycerin. Furthermore, the product yields of the biodiesel was 83 wt.% at 150 °C, which was considered to be the best experimental value.

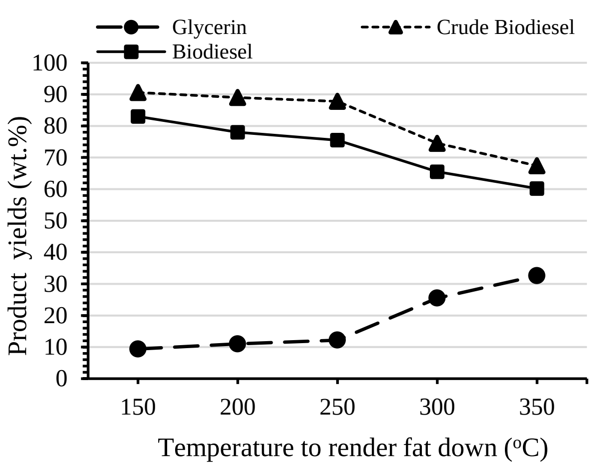


Fig. 7 Comparison of the product yields.

The fuel properties in Table 2 show the temperature to render fat down. The comparison of the optimal temperature for render fat down resulted in a similar calorific value of petroleum fuels. This raw feedstock from caw fat can be suitable for biodiesel production. Besides, their high cetane number and heating values are close to the diesel fuel [15]. The temperature at 250 °C increased the HHV to a maximum of 41.17 MJ kg^{-1}. In addition, the highest temperature significantly improved the quality of the fuel, thus reducing its viscosity. Thermal stability refers to the resistance offered by biodiesel to oxidation at high temperatures (>250 °C) [21].

Conclusion

This research studied the temperatures to render fat down from cow fat at 150 °C, 200 °C, 250 °C, 300 °C, and 350 °C, respectively, which affected the biodiesel oil yield. The transesterification reaction biodiesel production by using the base catalyst included methanol (CH_3OH) and sodium hydroxide (NaOH). The reaction temperature was controlled at 50 ºC. The temperature for the render fat down of less than 250 °C gave an acceptable FFA value, i.e., less than 3. The result found that the optimum temperature for rendering fat down was 250 °C because the biodiesel oil yield was 75.50 wt.%, the HHV had a maximum of 41.17 MJ kg^{-1}, and viscosity of 4.60 cSt. Furthermore, considering the render fat down duration, a longer time was required at a lower temperature. On the other hand, the exceeded temperature transformed beef tallow into fat, and crude oil became glycerol instead of biodiesel.

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