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Study of Reaction Conditions on a Conversion ratio of Castor Oil Fuel Production

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Abstract: Present paper is performed to production of biodiesel fuel BDF from castor oil CO. The effect of the molar ratio of alcohol to oil, temperature, and the type of catalyst factor on the efficiency of BDF production was studied. Esterification reactions were used to convert fat into fuel. The ideal molar ratio of methanol to oil is 1:7. The reaction temperature is 65°C, and the reaction time is 120 minutes. The concentration of the catalyst was 1% by weight of the CO. The conversion efficiency is 97% when using the above amounts. Potassium hydroxide is better than sodium hydroxide in esterification reactions. The physical specifications of the produced fuel are in accordance with the international specifications of ASTM, except for a tiny increase in viscosity. But it is within the permissible range. After completing the reaction process, the separation took two hours, unlike traditional techniques that take five days.

Keywords: BDF, castor oil, type of catalyst.

Introduction

Vegetable oil was a competitive alternative to diesel fuel. After World War, the world turned to fossil fuels, where they were available at reasonable prices due to the low cost of production. However, after the control of oil production by opic and the aggravation of the environmental pollution problem, it became necessary to search for alternative fuels [1-3]. Despite the difficulties found in vegetable oils of high viscosity and injecting into the internal combustion engine IC. However, these oils can become better used when converting the oil into esters, which have come to be called biofuels. Interest in diesel fuel has increased in recent years due to the high prices of hydrocarbon fuels and increased pollution [4-6]. Therefore, some standards have been set to ensure product quality, including the physical and chemical specifications of the ASTM and EU specifications [7,8].

BDF are a clean alternative fuel. It can be produced from renewable, biodegradable resources and is a non-toxic fuel free of sulfur and aromatic compounds. BDF can also be produced from animal fats and vegetable oils [14,15,16,17,18]. ASTM defines Biofuel as a long-chained mono alkyl ester produced from fatty acids taken from renewable sources in IC. The blended proportion of biofuels is indicated by (BX), where (X) is the blended proportion of biofuels [10].

Different vegetable oils were used to produce BDF. It turned out that sunflower oil was the best and had a high conversion efficiency, while cotton seed oil had a low conversion efficiency [11-13]. Biodiesel was produced from peanut oil. The highest conversion ratio was 88% using 1:6 alcohol to oil as molar ratio, knowing that the reaction temperature is 60°C. According to ASTM specifications, the characteristics of the fuel produced from peanuts were compared to those of fossil diesel. The viscosity at 40 °C was 5.908 mm²/s. The flash point is 192°C, the freezing point is 6°C, the spill point is 3°C, and the sulfur content is 0.0087 [14-17].

BDF was produced using the transesterification reaction of sunflower, rapeseed, olive, and frying oils with ethanol alcohol using sodium hydroxide as a catalyst. In the first stage, the ideal case of the esterification process gave the highest conversion rate of 95% by weight when the molar ratio was 1:12, alcohol: oil and sodium hydroxide 1% by weight and the reaction temperature was 80°C [18]. Next, BDF was produced using esterification reactions from different animal fats. Potassium hydroxide was used as a catalyst with a reaction time of 2 hours and a reaction temperature of 60°C. The results showed that the conversion rate was between (76.8% - 91.4% [19].

In this paper, biodiesel production from castor oil is studied using methanol alcohol as a solvent and sodium and potassium hydroxide as a catalyst for the reaction. The effect of temperature, the molar ratio of alcohol to oil and the type of catalyst on the efficiency of biodiesel production was used. As well as shortening the separation time from several days in the previous research to three hours after using the mixer for the product mixture.

Experimental work

1. Materials used in production

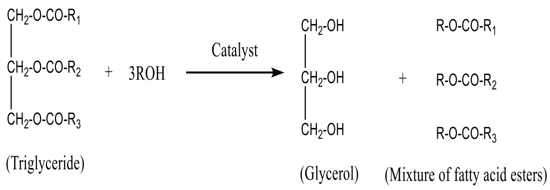
Castor oil, methanol and NaOH were used as essential catalysts for the reaction. Material specifications are as shown in Table 1, and Figure 1-A illustrates the materials used in the production of BDF.

Table 1. Specifications of materials used in the production of BDF

Material	Purity	Density	Molecular Weight	Product
Castor Oil	٪٩٩	967.3 Kg/M3	857 G/Mol	India
Laboratory Methanol	٪٩٩,٩	972 Kg/M3	32.04 G/Mol	Spain
Naoh	٪١٠٠	Solid	Solid	Germany
Koh	٪١٠٠	Solid	Solid	Germany

Method of Production of Biodiesel by Esterification Castor oil was heated to a temperature of up to 80°C for two hours to remove the excess water present in the oil. A sample of the oil is taken and added to the flask with the neck so that the oil reaches the reaction temperature, 60°C, 65°C and 70°C, with continuous stirring utilizing magnetic electrodes placed in the reaction flask. These electrodes rotate at a constant speed of about 700 rpm and then take a sample of methyl alcohol. The ratios of alcohol to oil that were taken are (1:6, 1:6.5, 1:7, 1:9, 1:12, 1:15) as molar ratios (Alcohol: Oil), which are the ideal ratios of alcohol to oil for different types of oils [20-22]. In addition to an amount of the catalyst, which is equivalent to 1% of castor oil by mass. Methyl alcohol is mixed with NaOH or potassium hydroxide KOH until the catalyst is completely dissolved and methoxide is formed. The methoxide is added to the reaction mixture with constant stirring of the mixture. With a reaction time of two hours for all experiments, the molar ratios of alcohol: oil were changed with a temperature change from (60-70) °C. Scheme1 shows the response of triglyceride with alcohol to form biofuels. Figure 1 (B-D) shows the Equipment used for the production of Biofuel.

The tests were conducted in the oil laboratories of North Refineries company–Baiji, Figure 2 (E-L) shows Apparatus Used to Measure Physical Properties of BDF.



Scheme 1: Reaction of Triglyceride with Alcohol

(a) Materials

(b) Three necks round bottom flask

(c) Mixer

(d)Separation Funnel

Figure 1. Materials and Equipment used for the production of Biofuel

E: Specific weight Device

F: Flashpoint Device

(g) POUR POINT Device

(h) U-tube Viscometer

(i)Koehler kinematic viscosity bath

(j)Residual Carbon bubble

(k)France

(l)Distillate

Figure 2. Apparatus Used to Measure Physical Properties of BDF

Results and Discussion

The alkyl esters of biodiesel were produced from castor oil through the transesterification process using methanol alcohol. Essential catalysts have difficulty forming ethyl esters compared to methyl esters, as primary catalysts have problems creating a stable emulsion with ethanol alcohol. Emulsions are more stable when using methanol alcohol because it facilitates the process of breaking bonds. The reaction mixture has two layers: an upper layer, which is alkyl esters, and a lower layer, which is glycerin [23, 24].

2. Properties of the produced biodiesel

Table 2 shows the physical properties of biofuels produced from castor oil.

Two catalysts were used: NaOH and KOH, where methoxide was used for both catalysts by reacting methanol with the catalysts. Biodiesel was produced using castor oil by fixing the molar ratio of alcohol to oil 1:7, with a reaction time of 2 hours, a catalyst concentration of 1%, and a reaction temperature of 65°C. With the essential catalyst type change from sodium methoxide to potassium methoxide, the highest conversion rate using NaOH was 46%. And the highest conversion rate for KOH was 97% by fixing the rest of the variables.

Table 2. The properties of produced biodiesel compared with ASTM.

Physical properties	B100	Property according to ASTM	Property limit
Specific gravity at 15.6 °C	٠,٨٧	ASTM D-941	0.860-0.900
API value	٣١,١٤	ASTM D-941	0-100
Kinematic viscosity at mm2/s at 40°C	١١,٨	ASTM D-445 (IP71)	1.9-6
Flash point °C	194	ASTM D93	130 min
Cetin number	50.19	ASTM D-6890	40.5-55.3
Pour point	-24	ASTM D-97	Unlimited
Water content %	٠,٥	ASTM D-2709	3.5%-5.0%
Residual carbon	٠,٠٠٠٨	ASTM D-524 IP14/65	0.05 max
Ash content mg/kg	٠,٠٢	ASTM D-6751-10	0.02 max
Distillation °C 90%	٣٣٤	ASTM D-6751-10	360 max

3. Effect of Catalyst Type on Conversion Efficiency of Castor Oil

The results indicate that the use of potassium methoxide is much better than the use of sodium methoxide. And the reason for this is the difficulty of dissolving sodium hydroxide in methanol alcohol, which negatively affects the conversion process because a large part of the catalyst does not interact, which is the main reason for this discrepancy. Therefore potassium hydroxide is better than sodium hydroxide in producing BDF [13, 25-27]. Figure (3) Effect of the type of catalyst on castor oil conversion ratios by fixing the molar ratio 1:7, reaction time 2 hours, temperature 65 °C, and catalyst concentration 1%.

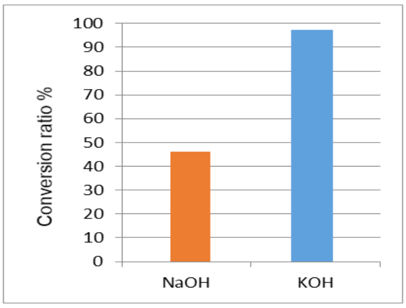


Figure 3. Effect of Catalyst Type on Conversion Efficiency of Castor Oil

4. Effect of Molar Ratio on Conversion Efficiency

The amount of alcohol added to vegetable oil is one of the most critical factors affecting the conversion efficiency when producing BDF. The conversion efficiency can be defined as the maximum processing and can be represented as a percentage. In general, the amount of alcohol required for the esterification reaction can be represented by the volume ratio.

The following molar ratios were used (1:6, 1:6.5, 1:7, 1:9, 1:12, 1:15), provided that the reaction time was 2 hours, the reaction temperature was 65 °C, and the amount of the catalyst was 1% by weight—the oil used in each experiment.

The molar ratio required to complete the reaction is 1:3 alcohol to oil, but this ratio does not give the best conversion efficiency of oil to esters. This is the formation of soap, which hinders the reactions, meaning that this amount of alcohol cannot complete the conversion process. The ideal ratio of alcohol to oil starts from 1:6, and the best ratio is 1:7. At a conversion ratio of 6:1, the production efficiency was 84%, and at 1:6.5, the percentage increased to 87%, indicating the low soap formation and ease of separation of glycerin. The ideal ratio is 97% when using a 1:7 molar ratio, which is the stage of the complete reaction. The amount of alcohol added to this ratio was sufficient to convert the oil. After increasing the percentage of alcohol from the ideal ratio and using 1:9 and 1:15, the conversion efficiency decreased, indicating an obstruction of the reaction by increasing the solubility of glycerine in the reaction solution. Increasing the ratio of alcohol to oil makes the solution more complex, which makes separating the glycerin from the reaction solution difficult. The soluble fraction of glycerin in the reaction solution has a density higher than that of esters. After placing the resulting fuel in the separating funnels, this fraction comes down with glycerine, separated from the methyl esters represented by BDF. As shown in Figure (4), the highest conversion rate was reached, approximately 97%. Figure (4) Effect of the ratio of alcohol to oil on the conversion efficiency of castor oil by fixing the concentration of the catalyst 1%, the temperature is 65 °C, and the reaction time is 2 hours.

5. Effect of Temperature on Conversion Efficiency

Three temperatures were used: 60 °C, 65 °C, and 70 °C, as the boiling point of methanol approaches (60 - 70) °C under atmospheric pressure [20]. Experiments were conducted by fixing the molar ratio of alcohol to oil 1:7, reaction time of 2 hours, and concentration of the catalyst factor 1%, with a temperature change between 60-70°C.

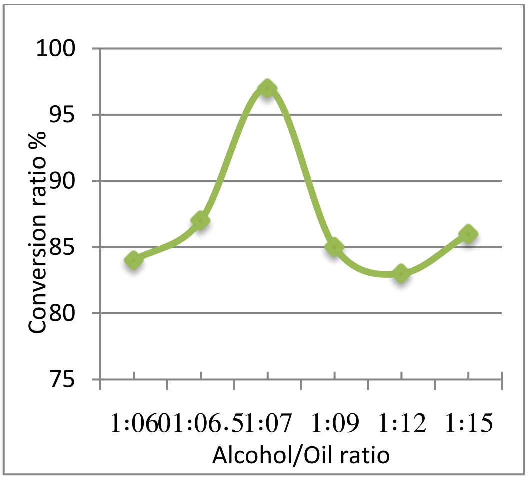


Figure 4. Effect of Molar Ratio on Conversion Efficiency

The conversion results were 89.5% with a temperature of 60°C, 97 % with a temperature of 65 °C, and 91.4% with a temperature of 70 °C. These results were directly affected by the approach of the reaction temperature to the boiling point of methanol alcohol. These results explain that the reaction was not completed at 60 °C because the efficiency of the solvent represented by methanol alcohol was not as high as possible. After all, it did not reach the boiling point, and at 65 °C, the conversion ratio of castor oil was ideal because it is equal to the boiling point of methanol alcohol. The temperature at the boiling point of methanol alcohol shows that the conversion efficiency has decreased because the alcohol has evaporated.

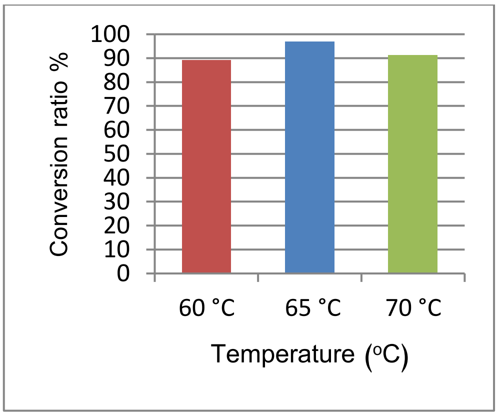


Figure 5. Effect of Temperature on Conversion Efficiency

Conclusions

a. The molar ratio of 1:7 is the best ratio for biodiesel production.

b. Potassium hydroxide is better than sodium hydroxide in esterification reactions.

c. The boiling point of methanol alcohol is the best temperature for esterification reactions in which methanol is used.

d. The use of a high molar ratio does not increase the conversion efficiency.

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