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BIODIESEL PRODUCTION FROM CASTOR OIL: MIXING OPTIMIZATION DURING TRANSESTERIFICATION

HishamE. Hassan[1], Yaser M. Asal[1], Ahmad M. Mohammad[2] and Islam M. Al-Akraa[1]
[1]Department of Chemical Engineering, Faculty of Engineering, the British University in Egypt, Cairo, Egypt
[2]Department of Chemistry, Faculty of Science, Cairo University, Cairo, Egypt
E-Mail: islam.ahmed@bue.edu.eg

ABSTRACT

With the growing warning for accrediting the traditional combustion of fossil fuels for energy production, not only for their limited supply but also for their environmental risks (air pollution, climate change, …. etc), it became necessary to realize alternative greener and abundant sources for energy. Instead, the interest to sustain biodiesel for the energy production has recently been renewed as a replacement for petroleum diesel in conventional diesel engines. This was due to its renewable nature, low toxicity, high degradability and unique physical properties (high flash points & lubrication). Castor oil, in particular, appeared promising for biodiesel production with extremely low cloud and pour points; making it suitable for tropical climates. Blending petroleum diesel with castor oil biodiesel has been proven efficient for enhancing both the environmental effect and the kinematic flow properties of the mineral fuel. Nonetheless, because of the current market price of conventional diesel, the blended product appeared cost-ineffective; steering research to tune the use of castor oil biodiesel alone. In this study, a simple method is recommended to produce biodiesel from castor oil by a transesterification process. The effect of mixing time of oil and alcohol is optimized with a thorough analysis to optimize the best condition for the biodiesel production.

Keywords: biodiesel; castor oil; transesterification; mixing time.

1. INTRODUCTION

Fossil fuel accounts for more than 80% of the world's primary energy consumption (EIA 2019). The burning of such traditional fuels emits large amounts of greenhouse gases (GHGs) that trap more heat which was supposed to escape out the atmosphere, "the greenhouse effect" (Munawer 2018). This definitely is the primary reason for increasing the temperature of the atmosphere and rising the problem of "Global Warming" that is being recently discussed in all climate talks and international events (Nations 2021). For example, the amount of CO_2 emitted by internal combustion is ca. 21.3 billion tons per year(Kazulis, Muizniece *et al*. 2017). Additionally, the combustion of such tradition fossil fuels produces a number of volatile organic compounds (VOCs), nitrogen oxides, carbon monoxides and particulates that can be inhaled. This is from one side. From the other side, as the world's population has risen over the years, the amount of energy consumed has increased. As a result, this warning alarm stimulated researchers to do something that save abundant clean energy sources for the next decades.

To guarantee that, a proper design, installation, operation and maintenance of traditional fossil fuels combustion systems could be made. From the other side, switching to clean and sustainable energy sources may considered ideal in both keeping the environment clean and offer a continuous supply on the long run (Al-Akraa, Mohammad *et al*. 2011, Al-Akraa, Mohammad *et al.* 2012, Al-Akraa, Mohammad *et al*. 2015, Al-Akraa, Mohammad *et al*. 2015, Al-Akraa, Mohammad *et al*. 2015, Al-Akraa, Mohammad *et al*. 2015, Al-Akraa, Mohammad *et al*. 2015, Mohammad, El-Nagar *et al*. 2015, Al-Akraa 2017, Al-Akraa, Mohammad *et al*. 2017, Al-Akraa, Asal *et al*. 2018, Al-Akraa, Asal *et al*. 2018, Al-Akraa, Mohammad *et al*. 2018, Mohammad, Al-Akraa *et al*. 2018, Al-Akraa, Asal *et al*. 2019, Al-Akraa, Asal *et al*. 2019, Al-Akraa, Asal *et al*. 2019, Al-Akraa, Ohsaka *et al*. 2019, Asal, Al-Akraa *et al*. 2019, Asal, Al-Akraa *et al*. 2019, Abdulhalim, Asal *et al*. 2020, Abuzaied, Asal *et al*. 2020, Al-Akraa, Al-Qodami *et al*. 2020, Al-Akraa, Al-Qodami *et al*. 2020, Al-Akraa and Mohammad 2020, Al-Akraa, Salama *et al*. 2021, Al-Qodami, Alalawy *et al*. 2021, Ali, Asal *et al*. 2021, Asal, Mohammad *et al*. 2021).

In this regard, biodiesel is receiving a great global attention because of its renewability, biodegradability, non-toxicity and being free of sulfur content (Prasada Rao, Victor Babu *et al.* 2017). In spite of its high emissions of NOx, its emissions from CO, CO_2, HC and smoke are too low(Chattopadhyay and Sen 2013). Moreover, it is compatible with all current infrastructures of diesel engine, so to implement it, no need to modifythe current engine technology (Demirbas 2009). Biodiesel are mostly obtained by the transesterification of vegetable oils or animal fats. In this reaction, triglycerides (TGs) react in presence of a catalyst with alcohols to produce diglycerides (DGs) that react again with alcohol to produce monoglycerides (MGs) that further react with alcohol to give ester and glycerol as a by-product, as following(Keera, El Sabagh *et al.* 2018):

$$TGs + ROH \xleftrightarrow{catalyst} DGs + RCO_2R \quad (1)$$

$$DGs + ROH \xleftrightarrow{catalyst} MGs + RCO_2R \quad (2)$$

$$MGs + ROH \xleftrightarrow{catalyst} RCO_2R\ (ester) + \text{Glycerol} \quad (3)$$

In this study, a simple method was used to produce a biodiesel from castor oil by the transesterification process. The effect of oil and alcohol mixing time will be optimized and an analysis of the best condition for biodiesel formation will be carried out.

2. EXPERIMENTAL

Methanol and potassium hydroxide (KOH)are used as the alcohol and catalyst, respectively, in the trans-esterifying of the castor oil (refined). Chemical reactions were performed in batch flow reactors, a reflux condenser, and a magnetic stirrer. First, the oil is preheated to 60^{o}C. Then the addition of methanol and catalyst was done. The mixing time was optimized (1, 2, 3, and 4 h) seeking the highest conversion percentage. After the mixing stage, the different phases were separated. The mixture was neutralized after extraction and, eventually, the biodiesel was washed away with double distilled water to remove any catalyst and alcohol residues till the water layer remained fully opaque.

3. RESULTS AND DISCUSSIONS

3.1 Yield

Figure-1 illustrates the methyl ester yield from methanolysis of castor oil using KOH as a catalyst at different reaction conditions (mixing times). According to the collected data, the yield increased as the mixing time increased till reaching 4 h of mixing at which the maximum yield was obtained (95.927 %). At longer mixing times (such as 5 h), the maximum yield did not change; inferring that 4 h was adequate for the best mixing between oil and alcohol mixture.

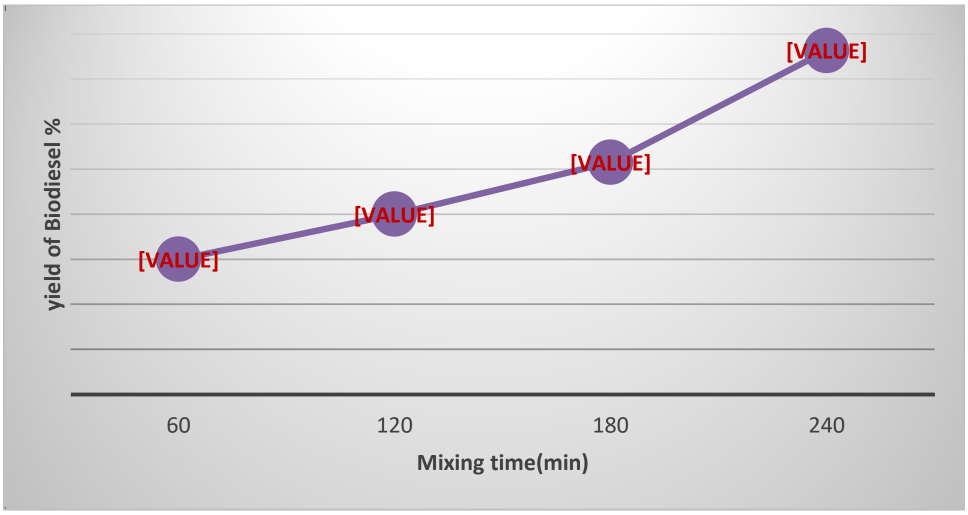

Figure-1. Mixing time effect on yield.

3.2 Biodiesel Analysis

3.2.1 Density

The sample density (0.9028g/cm^3) was found to be beyond the range of the international standard limit, according to the results in Table-1. The presence of a hydroxyl group in the ricin oleic acid methyl ester contributed to the dense character of the sample that was generated.

3.2.2 Viscosity

In the case of oil, viscosity is a measure of the internal fluid friction or resistance to flow that exists inside the oil, which tends to oppose any dynamic change in the fluid's motion. The viscosity of fats and oils plays a critical role in their transesterification into biodiesel. Biodiesel has a viscosity about one order of magnitude less than the crude oil or fat used to produce it. At 40 °C, castor oil has a viscosity of 231.22 cSt, as indicated in the Table-1. As a result, biodiesel produced from castor oil has a viscosity (9.565 cSt) higher than required in the market needs. This is because ricin oleic acid has OH groups, which allow hydrogen bonds formation with other hydrogen atoms in other compounds(Keera, El Sabagh *et al.* 2018).

Table-1. Estimated characteristic features that estimated for Castor oil, Diesel oil, and the produced Biodiesel (our case, 240 min).

Specification	Castor oil	Diesel oil	Biodiesel (240 min)
Density at 15.56 °C(g/cm^3)	0.9621	0.8379	0.9028
Kinematic viscosity at 40 °C(cSt)	231.22	2.42	9.565
Pour point (°C)	---	−6	-24
Cloud point (°C)	---	---	-13
Total Sulphur (Wt%)	Nil	0.85	Nil
Flash point (°C)	228	69	141.55
Calorific value (MJ/kg)	37.20	44	40.89
Cetane number	---	51	46.25

3.2.3 Cloud point and Pour point

Two critical properties of a fuel to consider while utilizing it at low temperatures are the cloud point (CP) and the pour point (PP). The cloud point (CP) is the temperature at which wax first becomes evident after cooling the fuel. At the PP temperature, the amount of wax evaporating from solution is sufficient to gel the fuel, and therefore the lowest temperature at which it may flow is the temperature at which the fuel may be injected. While it is well accepted that biodiesel has a higher CP and PP content than conventional diesel, methyl esters of castor oil have very low cloud and pour points, making this biofuel a feasible alternative in cold weather conditions. Table 1 shows the CP and PP of the produced biodiesel.

3.2.4 Sulphur content

As could be seen from Table 1, castor oil is completely free of Sulphur as reported previously (Prasada Rao, Victor Babu *et al*. 2017). As a consequence, the sample that is generated is devoid of Sulphur. This is one of the most significant advantages of using biodiesel. Low sulfur concentration is good to the environment, since it increases the engine's life span by extending its operating temperature range. A low Sulphur concentration in the exhaust is required in order to reduce exhaust emissions.

3.2.5 Flash point

When fuel is exposed to a source of heat, its flashpoint is the temperature at which it will spontaneously ignite. It is important in terms of hazardous material handling, storage, and transportation. A high flash point is well-known for its ability to provide increased safety during handling and storage activities. As shown in Table-1, Castor Oil has a value of 228 °C before transesterification and a value of 141.55 °C after transesterification, which is higher than the melting point of diesel (86.45 °C) indicating that it is safe to store.

3.2.6 Calorific value

It is the amount of thermal energy produced by the combustion process in the case of a unit value of fuel. As chain length increases and unsaturation decreases, the calorific value increases and becomes increasingly important in determining fuel consumption. The greater the calorific value, the less fuel is expected to be used. As Table 1 shows, it was 37.20 MJ/kg for castor oil and 40.89 MJ/kg for its biodisel.

3.2.7 Cetane number

Cetane number (CN) is a measure of biodiesel's ignition quality, and it diminishes as the chain length, branching, and unsaturation rise. The coefficient of (CN) is used to quantify heterogeneous fuel ignition delays, with higher values suggesting a shorter time interval between the commencement of fuel injection and ignition. The CN of diesel oil as shown in Table 1 is 51. Additionally, the ricin oleic acid molecule has double bonds, which decreases its CN. This is due to the presence of the castor oil molecule's free hydroxyl group, as well as the presence of the castor oil molecule's hydroxyl group. The CNfor the biodiesel was 46.25. This is less than the industry standard.

4. CONCLUSIONS

Castor oil has been recognized as one of the most promising choices for the production of biodiesel in laboratory. The conversion is accomplished via the use of an alkali transesterification process, after which the resulting biodiesel is described. With the exception of viscosity, the properties of castor oil biodiesel are within the biodiesel fuel standards. It is one of the most cheaply priced options available on the market today. Castor oil-derived biodiesel has very low cloud and pour points, making it an excellent alternative fuel for usage in chilly climates. Because of the present market pricing of conventional diesel, the final product may be preferred in terms of cost than conventional diesel in the long run. As a result, it may be used in a conventional diesel engine in the same way as regular diesel is burned.

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