

## BIODIESEL PRODUCTION FROM CASTOR SEED OIL AS AN ALTERNATIVE FUEL FOR THE COMPRESSION IGNITION (CI) ENGINE

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**Abstract-** In the current paper, castor seed oil (CSO) has been analyzed as a prospective source for biodiesel production in Bangladesh. The biodiesel production process was conducted in two stage (esterification and transesterification) processes to obtain the maximum yield of castor seed oil methyl ester (CSOME). The influence of oil to methanol ratio, catalyst content, production process, and important fuel properties are briefly discussed. The study revealed that the optimal conditions for the production of biodiesel were 1.50 wt. % KOH, 9:1 methanol to oil molar ratio, 60 min of reaction time, 60 °C reaction temperature, and 700 rpm rate of stirring. Under these circumstances, maximum yield of biodiesel was obtained. The physicochemical properties of CSOME were also characterized. Such studies helps in ascertaining the knowledge about biodiesel obtained from CSO which have analogous functional characteristics with diesel fuel and can be effectively utilized in compression ignition (CI) engines. In conclusion, the purpose of producing biodiesel from castor seed oil is prominently potential and can thus contribution in future energy requirements.

**Keywords:** CSO, CSOME, Biodiesel properties, Biodiesel yield

### 1. INTRODUCTION

The modern and progressive power and transportation sector of Bangladesh is heavily dependent on fossil fuels that decrease day by day [1]. Biofuel has attracted huge attention in different countries around the world recently because of its renewability, better gas emissions and its biodegradability. Non edible oils are increasing overall attention since they can be found in various region of the world. In addition, they can take out a challenge for food, more efficient, provide useful and valuable by-product, more environmentally friendly and they are more economical compared to edible oils. Non consumable oils are considered as a second generation biodiesel feedstock. Some of the non-edible oils are *Pongamia pinnata* (Karanja), *Calophyllum inophyllum* (beauty leaf), *Jatropha curcas* L. (JCL), *Thespesia populnea* L. (Milo), *Moringa oleifera*, *Croton megalocarpus*, *Azadirachta indica* (Neem), *Sapium sebiferum* L. , *Cerbera odllam* (sea mango), *Thevetia peruviana* Schum (yellow oleander), *Ceiba pentandra* (silk cotton tree), *Madhuca indica* (Mahua), *Eruca Sativa* Gars, *Madhuca longifolia*, *Hevea brasiliensis* (Rubber) and *Ricinus communis* L. (Castor oil). In any case, a large percentage of these non-edible oils has high free fatty acid (FFA) values. In this manner, transesterification with alkali based catalyst yields a considerable volume of soap. Soaps are emulsifiers that make the division of glycerol and ester phases more complicated. Further, the catalyst that has

been changed over to soap is never again accessible to accelerate the biodiesel production reaction. From this perspective, high catalyst stacking is required. Acid catalyzed transesterification was observed to be a better solution to this issue. However, the reaction rate was extensively less, requiring lengthy reaction periods. Consequently, it has been substantiated in the literature that the preminent methodology to produce biodiesel from non-edible oils with high FFA value is the acid esterification pursued by the alkaline transesterification process (acid-base catalyzed transesterification). Numerous ongoing publications have given an account of the prospect of biodiesel generation from non-edible oils such as references [2-6].

The production of biodiesel from non-edible oil is one of the effective approaches to meet future fuel demand. Increasing the usage of biodiesel will also decrease reliance on imported fuel that helps to eliminate a negative impact on the country's economy. The production of biodiesel has become very important in recent years as potential alternative to partially fulfill the expected future energy demands in the transport sector. Several methods have been reported for the production of biodiesel from vegetable or waste cooking oils and animal fats, including direct use and blending, micro emulsification, pyrolysis, and transesterification [7]. Transesterification is currently one of the most attractive and widely accepted methodologies for biodiesel

production [8]. Biodiesel is created through a conventional procedure known as transesterification, as appeared in figure 1.1 below, Where  $R_1$ ,  $R_2$ , and  $R_3$  are long hydrocarbon chains, sometimes called fatty acid chains. The conventional method for biodiesel production involves the use of homogeneous base catalysts under mild heating, although there are many others extended methodologies. Main factors affecting transesterification processes include reaction temperature, methanol to oil molar ratio, type and concentration of catalyst as well as purity of reactants. In any case, an excess of alcohol is normally utilized in the biodiesel production process in order to switch the equilibrium to the production of esters (with glycerol as main by-product) through a stepwise process.

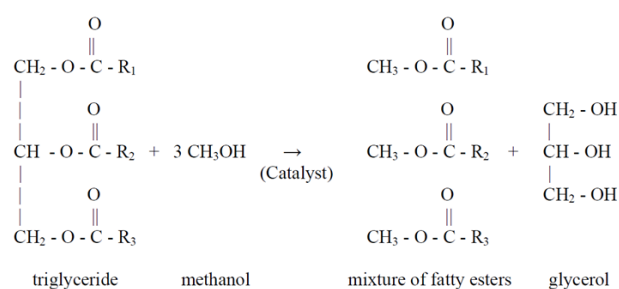


Figure 1.1: Transesterification reaction of triglyceride [9]

Many researchers all over the world studied the production of biodiesel from different sources, but a very few researcher [10] studied the Castor seed oil biodiesel optimization and production. Jahirul et al. [5] was investigated the optimization of biodiesel from beauty leaf oil seed. Mofijur et al. [11] studied the prospects of biodiesel production from macadamia oil as an alternative fuel for diesel engines. They found that macadamia oil can be a possible source for biodiesel production and up to 20% macadamia biodiesel can be used as a fuel in diesel engines without modifications. Shrirame et al. [12] studied the production of biodiesel from CSO but the details data on CSOME is not presented in his study. Similarly, there are various studies establish on the assessment of biodiesel from different edible and non-edible oil in diesel, but there is a lack of research on the production of CSOME optimization and production as an alternative fuel for diesel engines.

The objectives of this research are to produce biodiesel from non-edible castor seed oil using two stages (esterification and transesterification process), to optimize the process parameters such as catalyst concentration, methanol to oil molar ratio, reaction temperature, and reaction time and to characterize the properties of CSOME.

## 2. MATERIALS AND METHOD

### 2.1 Materials

The CSO was purchased from the local market known as Pitombor Shah, anderkilla, Chittagong, Bangladesh. The chemical products were purchased from Taj scientific, Chittagong and all other equipment were available in our metallurgy laboratory, department of

mechanical engineering. All the chemicals applied in this study were of analytical grade.

### 2.2 Production Process of CSOME

To split the production process of CSOME in two categories, we have to go through with the following process i.e. Esterification and transesterification.

With the uses of anhydrous  $\text{H}_2\text{SO}_4$  (acid catalyst), triglycerides had been gotten which was transformed from high FFA CSO in a pretreatment process with methanol. The variables affecting in acid esterification such as methanol to CSO molar ratio and acid catalyst concentration were completely scrutinized to maximize the yield of FFA to triglycerides. At the presence of  $60 \pm 2^\circ\text{C}$ , the reaction was conducted for 60 min. After completing the first stage of the acid esterification, the product was shifted to a separating funnel, in which the excess methanol along with impurities moved to the upper portion of the separating funnel and was removed. The lower portion had been taken for the alkali transesterification.

The product of lower portion obtained through acid esterification was heated at the desired temperature before starting the reaction. The concoction of potassium hydroxide and methanol solution had been done. The alkali methoxide solution was compounded with the preheated product obtained through the acid esterification while mixing with the aid of a magnetic stirrer are placed in a reactor to perform transesterification process. The product was kept in a separating funnel at a steady state to settle under gravity for 6 to 8 hours. Two layers are formed by the products of the alkali transesterification process viz., an upper layer containing a mixture of small quantities of unreacted oil, glycerol and transesterified products (esters) and a lower layer of glycerol. The lower layer of glycerol had been removed. To remove the rest of the methanol, the upper layer was heated to  $70\text{--}80^\circ\text{C}$ . The obtained product was a CSOME i.e. biodiesel. At the presence of  $60^\circ\text{C}$ , the CSOME was compounded gradually with distilled water ( $30^\circ\text{C}$  (volume of distilled water to volume of biodiesel)) in purpose to remove impurities like catalysts. In order to remove moisture contents, the final product was again heated to  $100\text{--}110^\circ\text{C}$  for 20 min after washing. The mixture was subsided under gravity for 8 to 10 hours. Then the collection and storage process of final product was held for characterization. The yield of CSOME was more than 90%, which was calculated using following Equation [13]:

$$\text{CSOME yield (\%)} = \frac{\text{weight of the purified CSOME(g)}}{\text{Total weight of the CSO used (g)}} \times 100$$

Figure 2.1 illustrate the overall production process of CSOME.

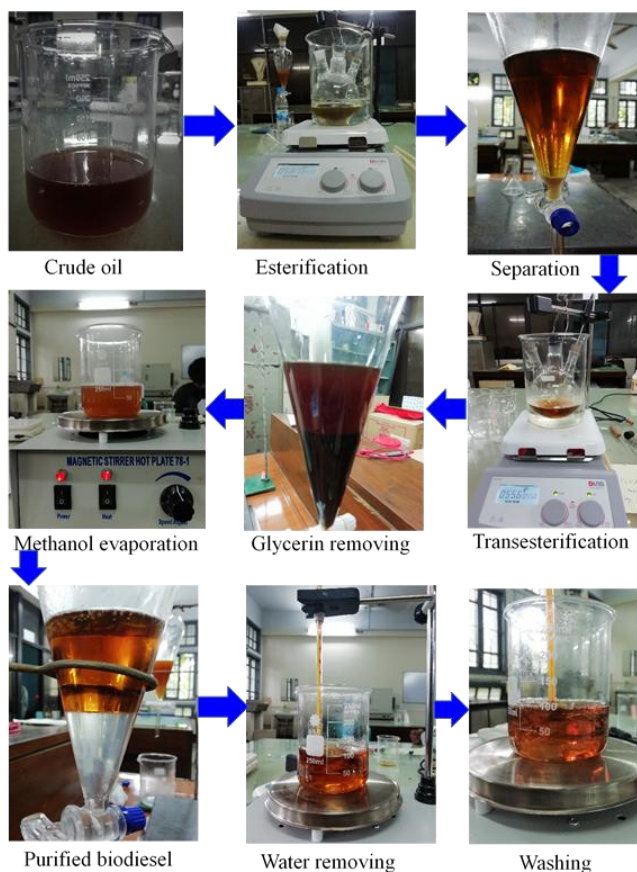


Figure 2.1: Biodiesel production process

### 3. RESULTS AND DISCUSSION

The effects of catalyst concentration, methanol to oil molar ratio, reaction time and reaction temperature on biodiesel yield was analyzed.

#### 3.1 Optimization of Catalyst Concentration

Figure 3.1 illustrate the yield of CSOME at a number of catalytic concentrations (0.5-2 wt. %), the response time 60 min while keeping up the methanol: oil molar ratio 9:1, reaction temperature is set for 60°C. It can be perceived that the lower catalyst concentration of 0.5% KOH is inadequate for the finish of reaction; the yield of CSOME is 68%. By growing the catalyst concentration to 1.5 %, the yield of CSOME increments to 92%. Further increment in the catalyst concentration creates a yield decrease. This conduct is because of the high concentration of an alkaline catalyst which causes the saponification reaction which are responsible for forming soaps within the sight of fatty acids resulting in emulsion formation between soaps and water particles [14].

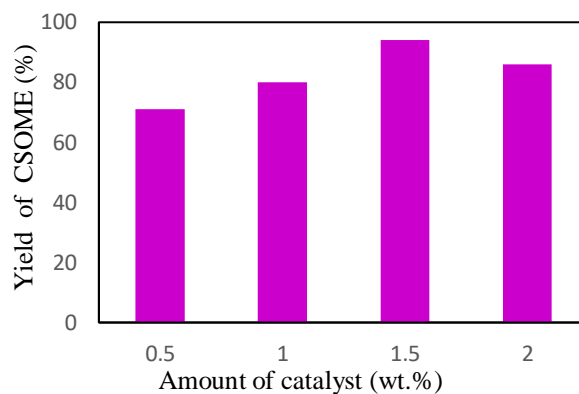


Figure 3.1: Yield of CSOME at different catalyst concentration

#### 3.2 Determination of Optimum Molar Ratio of CSO: Methanol

From the figure 3.2, it is clear that the optimal mole ratio of oil: methanol was 1:9. The yield of biodiesel remained constant as obtained from a series of experiments that were carried out at different concentrations of methanol and the quantities of CSO. This was done at constant temperatures of 60°C. This is because the one mole of oil maintained for the series of experiments, which were done, had a given maximum number of molecules to take part in a chemical reaction. These molecules were all used at the mole ratio of 1:9 and thus the yield could no longer increase beyond this figure.

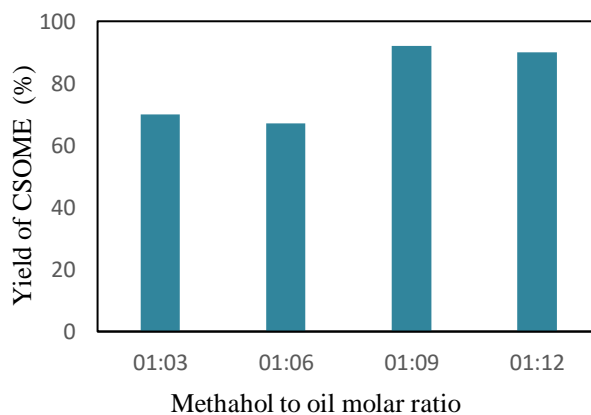


Figure 3.2.: Yield of CSOME at different molar ratio

#### 3.3 Optimization of Reaction Time

To determine the optimum amount of time for the process, the mole ratio of oil to alcohol was kept constant at 1:9 and then the time will be varied for 30 to 120 minutes and the amount of biodiesel was obtained recorded to determine the optimum amount. In figure 3.3 represents the percentage of CSOME yield with respect to reaction time.

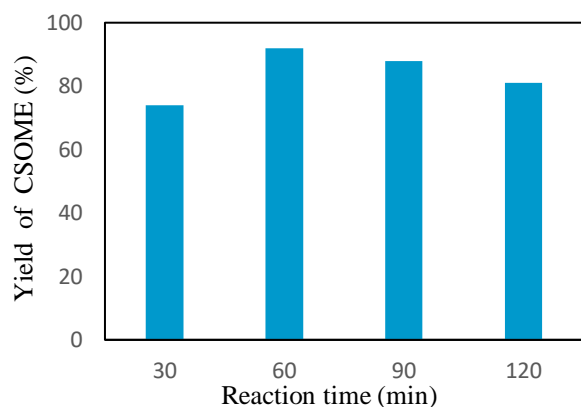


Figure 3.3: Yield of CSOME at different times

### 3.4 Optimization of Reaction Temperature

The reaction temperature is another significant parameter that will influence the yield of biodiesel. An analysis was kept running at the ideal condition, 1.5 wt. % catalyst, the reaction time (30 to 120 min), and methanol to oil molar proportion 9:1, and temperature 60°C. It is represented that the consistent condition of the response is come to inside a brief timeframe (30 min) on account of the extremity of methanol and ricinoleic acid, giving raised miscibility of castor oil in methanol. This occurred because of the perfect miscibility of CSO in methanol at room temperature. However, after 60 min of the response, this variable isn't to some degree significant. Obviously the CSOME yield somewhere in the range of 30°C and 60°C changes by just 2% wt. henceforth the reaction to happen at 60°C is truly appropriate. The effect of reaction temperature for yielding of CSOME has been shown in figure 3.4.

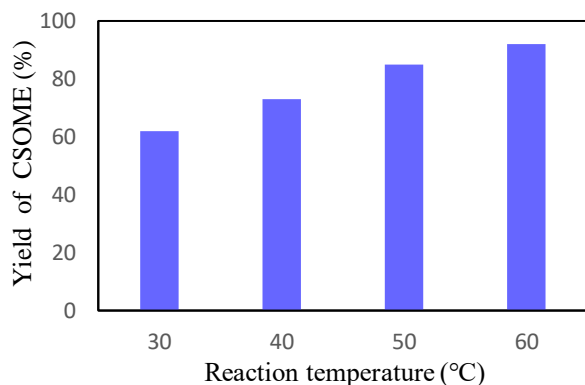


Fig.3.4: Yield of CSOME at different reaction temperature

### 4. CONCLUSIONS

The fuel characteristics of CSOME were analyzed and compared with diesel. Table 4.1 shows the fuel properties of CSOME. It was found that the kinematic viscosity of CSOME is 12.3 mm<sup>2</sup>/s and the acid value lowered to 1.04 mg KOH/g. The Flash point was found 176°C, which is much higher than diesel fuel (47°C) that indicates CSOME fuel is safer to operate and storage. The calorific value of CSOME were found 36.48 MJ/kg.

Table 4.1: Properties of CSOME in comparison with diesel

Sl. no	Properties	CSOME	Diesel
1	Density (kg/m <sup>3</sup> )	913.40	830
2	Flash point (°C)	176	47
3	Kinematic viscosity (mm <sup>2</sup> /s)	12.30	6.0
4	Calorific value (MJ/kg)	36.48	45.30
5	Acid value (mg KOH/g)	1.04	0.0

CSOME i.e. acquired biodiesel were successfully prepared from non-edible CSO. The process parameters, such as catalyst concentration, methanol to oil molar ratio, reaction time and reaction temperature were optimized and the highest yield (92 wt.%) was produced using 1.50% KOH w/w, 9:1 methanol to CSO blend molar ratio, 60°C reaction temperature, 60 min of reaction, and 700 rpm rate of stirring. CSOME fuel properties are within the recommended standards of biodiesel fuel except the viscosity. Finally, it can be suggested that CSO can be a potential source for CSOME production and CSOME can be used as a fuel for diesel engines as a blend of diesel fuel without any modification

### 5. ACKNOWLEDGEMENT

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### 6. REFERENCES

- [1] A. E. Atabani and S. César, "Calophyllum inophyllum L.—A prospective non-edible biodiesel feedstock. Study of biodiesel production, properties, fatty acid composition, blending and engine performance," *Renew. Sustain. Energy Rev.*, vol. 37, pp. 644–655, 2014.
- [2] A. S. Silitonga, A. E. Atabani, T. M. I. Mahlia, H. H. Masjuki, I. Anjum, and S. Mekhilef, "A review on prospect of *Jatropha curcas* for biodiesel in Indonesia," *Renew. Sustain. Energy Rev.*, vol. 15, no. 8, pp. 3733–3756, 2011.
- [3] A. Kumar and S. Sharma, "Potential non-edible oil resources as biodiesel feedstock: An Indian perspective," *Renew. Sustain. Energy Rev.*, vol. 15, no. 4, pp. 1791–1800, 2011.
- [4] M. M. K. Bhuiya, M. G. Rasul, M. M. K. Khan, N. Ashwath, and A. K. Azad, "Prospects of 2nd generation biodiesel as a sustainable fuel-Part: 1 selection of feedstocks, oil extraction techniques and conversion technologies," *Renew. Sustain. Energy Rev.*, pp. 1–20, 2015.
- [5] M. I. Jahirul et al., "Optimisation of bio-oil extraction process from Beauty Leaf (*Calophyllum inophyllum*) oil seed as a second generation biodiesel source," *Procedia Eng.*, vol. 56, pp. 619–624, 2013.
- [6] W. M. J. Achten et al., "Jatropha biodiesel production

- and use,” *Biomass and Bioenergy*, vol. 32, no. 12, pp. 1063–1084, 2008.
- [7] Ribeiro, N. M. et al. (2007). The Role of Additives for Diesel and Diesel Blended (Ethanol or Biodiesel) Fuels: *A Review. Energy & Fuels*, 21(4), 2433–2445. Doi: 10.1021/ef070060r.
- [8] C. Verdugo et al., “Production of a new second generation biodiesel with a low cost lipase derived from *Thermomyces lanuginosus*: Optimization by response surface methodology,” *Catal. Today*, vol. 167, no. 1, pp. 107–112, 2011.
- [9] F. Acids, V. Oil, N. K. Patel, and S. N. Shah, “Transesterification Learn more about Transesterification Biodiesel from Plant Oils Heteroatom Manipulation,” 2015.
- [10] A. R. M. F. Nivea De Lima Da Silva, Maria Regina Wolf Maciel, César Benedito Batistella, “Optimization of Biodiesel Production from Castor Oil,” *Appl. Biochem. Biotechnol.*, vol. 129, 2006.
- [11] M. Rahman, M. Rasul, N. S. Hassan, and J. Hyde, “Prospects of Biodiesel Production from Macadamia Oil as an Alternative Fuel for Diesel Engines,” 2016.
- [12] H. Y. Shirame, N. L. Panwar, and B. R. Bamniya, “Bio Diesel from Castor Oil – A Green Energy Option,” *Low Carbon Econ.*, vol. 02, no. 01, pp. 1–6, 2011.
- [13] Fadhil AB. Evaluation of apricot (*Prunus armeniaca* L.) seed kernel as a potential feedstock for the production of liquid bio-fuels and activated carbons. *Energy Convers Manage* 2017; 133:307–17.
- [14] K.G. Georgogianni, M.G. Kontominas, P.J. Pomonis, D. Avlonitis, Conventional and in situ transesterification of sunflower seed oil for the production of biodiesel, *Fuel Process. Technol.* 89 (2008) 503–509.