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SAFFLOWER OIL METHYL ESTER: OPTIMIZATION OF TRANSESTERIFICATION PROCESS AND FUEL CHARACTERIZATION FOR C.I. ENGINE PERFORMANCE

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KEYWORDS: Safflower oil (SO), Transesterification, Optimization, Safflower oil methyl ester (SOME), Fuel properties.

ABSTRACT
In the present work, the production of biodiesel using safflower oil (SO) in an alkaline catalyzed transesterification reaction was investigated. The effect of different parameters including methanol to oil molar ratio (4:1, 6:1), potassium hydroxide concentration (0.5 %, 1.0%, 1.5 %) and reaction time (60 min, 75 min, 90 min) on the production of biodiesel were investigated. The result indicated that these parameters were important factor affecting the transesterification reaction. The fuel properties of biodiesel including viscosity were measured. The methyl ester production methodology is prime aspect for efficient and cost-effective production of methyl ester. The present investigation concentrated on the distinct technical aspects of methyl ester production methodology. As per consideration of maximum biodiesel yield and minimum viscosity, the optimized biodiesel yield and viscosity were evaluated as 95.22% and 5.63 centipoise respectively as per optimized process parameters. The properties of SOME were found to be close to that of diesel fuel and also they satisfied the ASTM standards.

INTRODUCTION
Due to increase in energy demand, drop in petroleum fuel reverses, growth in pollution affected by them and increasing fuel values have focused consideration on substitute or alternative sources of energy. The indiscriminate consumption of fuel also leads to energy depletion and several studies have indicated that petroleum reverses will near an end between 2050 and 2075, which has triggered many initiatives to search for alternative fuel. Biodiesel is not only to ensure energy security, but also delivers renewable, harmless, eco-friendly and cleaner energy source with properties similar to diesel [1]. As the fossil fuels are depleting day by day, there is a need to find out an alternative fuel to fulfill the energy demand of the world. Biodiesel is one of the best available sources to fulfill the energy demand of the world. The petroleum fuels play a very important role in the development of industrial growth, transportation, agricultural sector and to meet many other basic human needs. However, these fuels are limited and depleting day by day as the consumption is increasing very rapidly. Moreover, their use is alarming the environmental problems to society. Hence, the scientists are looking for alternative fuels. Biodiesel is gaining more and more importance as an attractive fuel due to the depleting nature of fossil fuel resources [2]. Biodiesel is one of these promising alternative resources for diesel engines. It is defined as the mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats and alcohol with or without a catalyst. It is renewable, biodegradable, environmentally friendly, non-toxic, portable, readily available and eco- friendly fuel [3–6]. Biodiesel, formally known as either methyl-ester or ethyl-ester, is a natural occurring vegetable oil or animal fat which has been chemically modified to run in a diesel engine [7]. Biodiesel's many advantages compared to petroleum diesel like its renewable nature, better emissions properties, support for domestic agriculture, compatibility with existing engines and ease of manufacture [8]. The catalyst concentration is determined by the difference in molar ratio, catalyst type and oil properties considered in the reaction process involved [10]. The reaction temperature is a vital factor impelling the yield of biodiesel and reaction rate. The transesterification is generally carried out at a temperature in the range of 25°C to 120°C, depending on the type of catalyst and oil used [1, 9-11].

The objective of present investigation was based on the optimization of methyl ester production derived from safflower and kusum seed oil. The optimization of methyl ester was carried out by transesterification reaction with involving different process parameters i.e. methanol/oil molar ratio, % catalyst concentration and reaction time.

MATERIALS AND METHODS

Materials

The safflower and kusum seed oil were collected from local dealer available in Patiala. 99.9% pure methanol and analytical grade catalyst potassium hydroxide (in pellet form) were used in biodiesel production. All reagents were available in our chemical engineering laboratory.

Apparatus

The equipment used for transesterification reaction is water bath shaker, reaction flask with digital temperature indicator for measuring reaction temperature and digital rpm meter for controlling mechanical stirring.

Experimental procedure

The transesterification reaction of safflower oil was carried out in the following steps: [12]

- Firstly, the oil was heated up to 50 °C in a borosil 500 ml flask and it was kept at this constant temperature. For obtaining homogenous mixture of reactants, a magnetic stirrer was employed.
- The amount of methyl alcohol as per molar ratio was mixed with catalyst KOH and it was heated 30-40 °C until the catalyst was completely dissolved in alcohol. Now this homogeneous mixture of alcohol-catalyst mixed with preheated safflower oil.
- The mixture of oil-alcohol-catalyzer was heated at constant temperature of 55–60 °C and it was stirred simultaneously at about constant 1000 rev/min. in the reaction cap for 2 h.
- After 2 h of reaction time, the products were filled into a washing and separation funnel. The reaction products were separated into two layers, the top one was biodiesel and the bottom one was glycerol.
- The biodiesel was then washed with hot water to separate the probably remained alcohol or catalyst from biodiesel. It was then kept for 4 h in the cap to separate the water. Finally, the biodiesel was heated above 100 °C to remove the remaining water from biodiesel fuel.

RESULTS AND DISCUSSION

Properties of safflower oil

Feed stock	Safflower oil	Optimized fuel properties
Density at 15 °C (kg/m^3)	920.5	874.91
Kinematic viscosity at 40 °C (cSt)	30.20	5.63
Heating value (MJ/kg)	40.12	42.09
Flash point (°C)	227.9	170.50
Pour point (°C)	-10	-15.33
Cloud point (°C)	-2	-4

Effect of parameters on transesterification of safflower oil and kusum oil

This section presented the influence of various process parameters such as molar ratio, catalyst concentration and reaction time etc. on biodiesel production from safflower oil and kusum oil by transesterifiction process.

Effect of % catalyst concentration and reaction time on SOME formation

In this experimental study, catalyst KOH was used in transesterification reaction due to its low cost and effective in nature. This experimental work was carried out using 4:1, 6:1 methanol/oil molar ratio with differ catalyst concentrations and reaction times and at constant reaction temperature of 60°C. The influences of these parameters on methyl ester production are shown in Figure 1 and Figure 2.

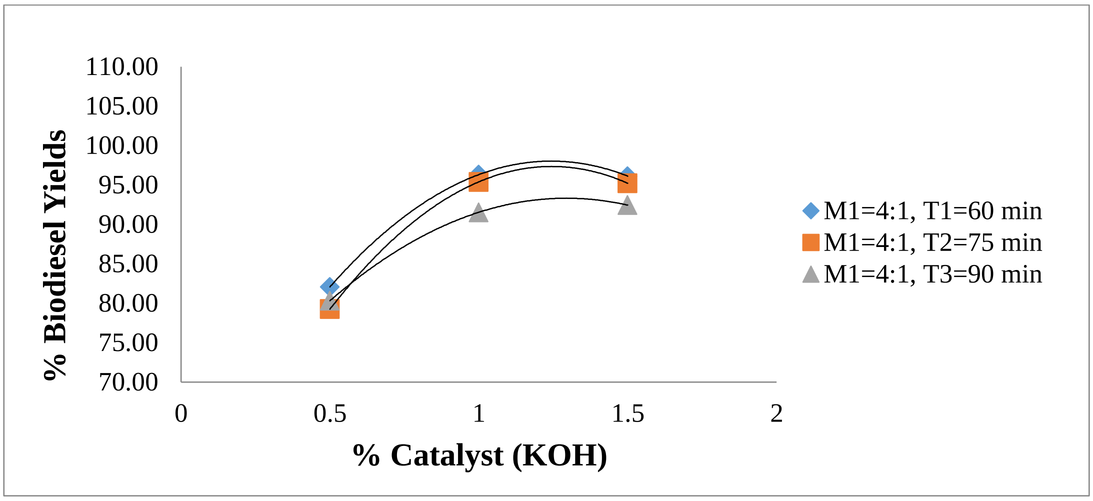

Figure 1 Variation of SOME yield with KOH concentration and reaction time at 4:1 molar ratio

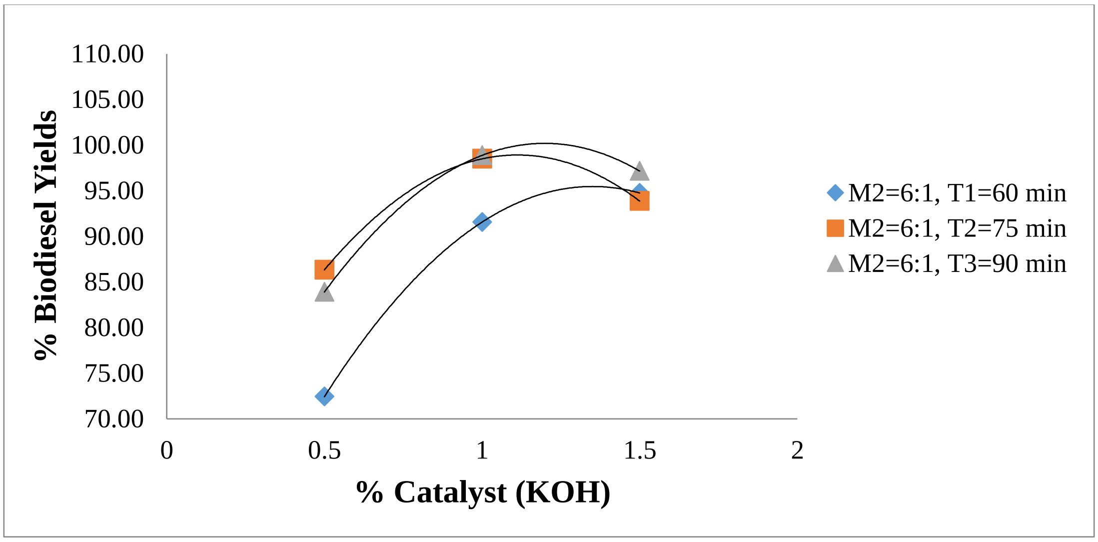

Figure 2 Variation of SOME yield with KOH concentration and reaction time at 6:1 molar ratio

The results found that catalyst concentration was a significant influencing parameter of transesterification reaction. As concentration of catalyst is raised from 0.5% to 1.5%, both Figure 1 and Figure 2 show that increasing trend of methyl ester formation at 30 minutes reaction time. Further increasing in % amount of catalyst concentrations were responsible of decreasing of methyl ester formation due to incomplete reaction because of soap formation. This is due to high FFA content present in the oil which deactivated the catalyst and present extra catalyst was responsible to form emulsion which raised the viscosity, lead to form gels and difficulty associated with glycerol separation and loss in ester yield [1].

It is also seen that reaction time is an important factor in production of biodiesel. As increasing reaction time from 60 minutes to 90 minutes, the yield grows or drops depending upon % catalyst concentration. The maximum yield is obtained 98.88% with catalyst concentration 1% at 90 minutes reaction time.

Effect of methanol/oil molar ratio and reaction time on SOME formation
After analysis of effect of catalyst concentration, it is observed that the maximum yield of biodiesel was obtained at 1.5% catalyst concentration. Figure 3 shows the influence of molar ratio and reaction time on methyl ester yield at reaction temperature 60° C with 1% catalyst concentration. It was noticed that as the methanol/oil molar ratio

increases from 4:1 to 6:1, the yield also increase with respect to reaction time. The cause is this, transesterification reaction is reversible in nature due to this additional methanol is needed to shift the equilibrium towards product side (higher yield of methyl ester) [13]. But generally higher molar ratio is not selected because of more consumption of energy required for recovering unreacted methanol and presence of excess methanol suspended into by product glycerin which is responsible to makes separation difficult. It is also observed that maximum methyl ester yield i.e. 98.88% was acquired with 6:1 molar ratio at 90 minutes reaction time.

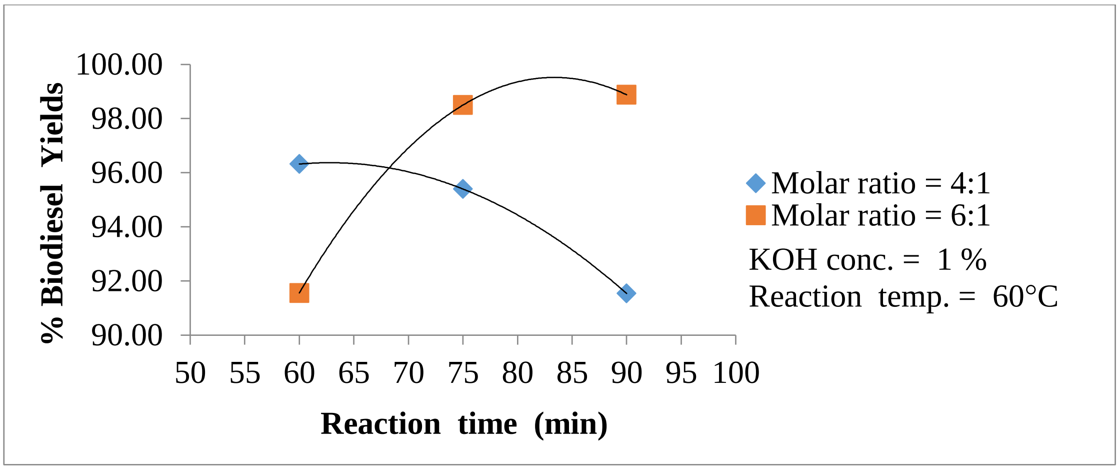

Figure 3 Variation of SOME yield with molar ratio and reaction time at 1% KOH concentration

Effect of methanol/oil molar ratio and reaction temperature on SOME viscosity

The influence of increasing molar ratio and catalyst KOH concentration was illustrated in the Figure 4. It was found that as the molar ratio increases from 4:1 to 6:1, viscosity of methyl ester increases. This is due to excess molar ratio increase the methanol solubility in glycerin which makes separation difficult and the remains glycerin in solution cause high viscosity of methyl ester. As per project requirement, the minimum viscosity has been obtained at 4:1 molar ratio and 75 minutes reaction time.

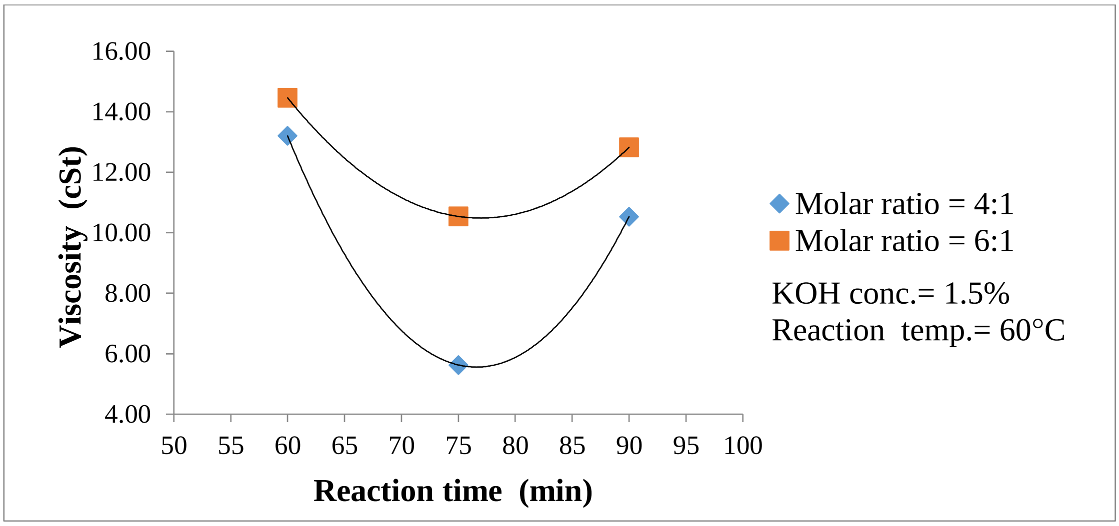

Figure 4 Variation of SOME viscosity with molar ratio and reaction time at 1.5% KOH concentration

CONCLUSION

From the detailed literature survey on safflower oil methyl ester, the following conclusion can be made:

- The maximum methyl ester yield i.e. 98.88% was acquired with 6:1 molar ratio, 1% catalyst concentration and 90minutes reaction time.

- As per consideration of maximum biodiesel yield and minimum viscosity, the optimized process parameters for safflower oil methyl ester production were 4:1 molar ratio, 1.5% KOH catalyst concentration and 75 minutes reaction time. The optimized biodiesel yield and viscosity were evaluated as 95.22% and 5.63 centipoise respectively as per optimized process parameters.
- The parameters such that methanol/oil molar ratio, % catalyst concentration and reaction time were playing the most important role in production of methyl ester.

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