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Research Note

Optimum Production of Biodiesel from an Underutilized and Potential Feed stock, Kusum Seed Oil

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P A P E R I N F O

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A B S T R A C T

Day by day the energy consumption is very rapidly increasing. The world's fossil fuel supply will be depleted in future. The rate of energy consumption is increasing the supply is depleted resulting in inflation and energy shortage. This is called the energy crisis. Alternate or renewable energy resources are very essential to develop for future energy requirement. Biodiesel is the best alternative to petro-diesel. The present research work deals with the production of biodiesel from Kusum oil. Kusum oil methyl ester (KOME) was produced using a two-stage esterification cum transesterification process on account of the high free fatty acid (FFA) contents of the oil. From the above study it may be concluded that Kusum oil is a promising feedstock for biodiesel production and may be the best alternative of petro-diesel The biodiesel property of Kusum oil methyl ester (KOME) has been characterized and it shows that KOME meets the properties of biodiesel as stated in ASTM/EN standards.

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INTRODUCTION

Biodiesel is derived from vegetable oils and animal fats which has recently gained interest as a possible alternative to conventional fossil diesel due to the rapid decrease in fossil fuel and growth in population along with industrial development. Biodiesel is a biodegradable, renewable and nontoxic fuel and its application as a diesel engine fuel improves exhaust emissions, with great potential to decrease environmental pollution [1-3]. The main procedures for the production of biodiesel are direct use or blending of vegetable oil with solvents and physico-chemical methods, such as micro-emulsification, pyrolysis and transesterification. However, biodiesel is commonly formed from the triglycerides in vegetable oils via transesterification. The transesterification reaction is influenced by several experimental parameters, such as molar ratio of alcohol to oil, catalysts type and concentration, as well as the reaction conditions. In order to improve yields of biodiesel and the reaction rate, the following experimental parameters have to be considered; the molar ratio of alcohol to oil is one of the most important parameters capable of affecting the yield of biodiesel [4-6]. The transesterification with a basic catalyst is generally much faster than that with an acidic catalyst, but the reaction catalyzed by an acid catalyst results in a very high yield of biodiesel [7]. It is evident that most of the work has been focused on edible oils and a small quantum of work has been carried on non-edible oils for biodiesel production and its subsequent utilization. It is also pertinent to note that amongst the non-edible oils, Jatropha,Karanja, Mahua and some other feed stocks have been explored.However, Kusum oil, which is a underutilized non-edible vegetable oil in India, is not adequately studied. The present work dealswith the production and optimization of biodiesel production from Kusum oil and its physico-chemical characterization.

MATERIAL AND METHODS

Kusum oil have been used for biodiesel production in the present study was purchased from an oil industry of Delhi (India) and commercially available petro-diesel oil was purchased from the nearby petrol pump. Anhydrous methanol (99.8% min.), Sulphuric acid (90 % min.) and Potassium hydroxide (85% min.) was purchased from chemical store.

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Kusum oil

The botanical name of Kusum is *Schleichera oleosa* and the potential of Kusum oil is 66, 000 tonnes per year in India. It mainly occurs insub-Himalayan tracts in the north, central parts of eastern India. The oil content is 51–62% but the yields are 25–27% in village ghanis (oil mills) and about 36% oil in expellers. It contains only 3.6 to 3.9% of glycerin while normal vegetable oil contains 9–10% glycerine. FFA (Free fatty acid) present in oil is 5–11%. Iodine value is 215–220 and total fatty acidcontent is 91.6%. Table 1 shows the fatty acid composition of Kusum oil. Fig. 1 presents the various parts of the tree seeds and its oil.

Table 1. Fatty acid composition of Kusum oil

Fatty acids	Chemical formula	Degree of of unsaturation	Kusum Oil
Palmitic	$C_{16}H_{32}O_2$	16:0	6.73
Palmitoleic	$C_{16}H_{30}O_2$	16:1	2.88
Stearic	$C_{18}H_{34}O_2$	18:1	5.81
Oleic	$C_{18}H_{32}O_2$	18:2	48.51
Linoleic	$C_{20}H_{40}O_2$	20:0	6.57
Arachidic	$C_{20}H_{38}O_2$	20:1	27.21

It may be observed in Table 1 that the KOME is rich in oleic acid. Besides, the saturated fatty acids account for nearly 58% and unsaturated fatty acids were nearly 41%, as indicated by the gas chromatography apparatus. High saturated fatty acid composition led to superior storage stability, as manifested by the higher oxidation stability explained earlier. Similarly, the CFPP of saturated fatty acids are poor. This may be explained by the inferior CFPP exhibited by the KOME sample.

Production and characterization of KOME and blends

Biodiesel was produced using transesterification process in which, the triglycerides was reacted with methanol in presence of KOH as catalyst. The free fatty acid (FFA) content of the Kusum seed oil was more than 2%, so a two stage transesterification process was used to produce Kusum oil methyl ester. The transesterification was conducted using 0.1% (w/w) phydroxide as catalyst, 60^0C reaction temperature and 60 min reaction time with constant stirring at 450 rpm.The physico-chemical properties were evaluated for all test fuels taking into considerations.

Transesterification process

Chemically transesterification is defined as the reaction of triglyceride molecule of vegetable oil or animal fat with a simple alcohol such as methanol, ethanol, butanol or iso-propanol to form esters and glycerol. [8-11]. in simpler terms transesterification is the conversion of heavy oils or fats into a less viscous fluid that is suitable for combustion in a conventional diesel engine (Eq. 1). The esters are used as biodiesel fuel. This method is generally the preferred and most probably the best option to making biodiesel. Biodiesel can be used in pure form, or blended with petroleum diesel for use in compression ignition engines. The physical and chemical properties of biodiesel fuel are similar to petroleum diesel fuel.

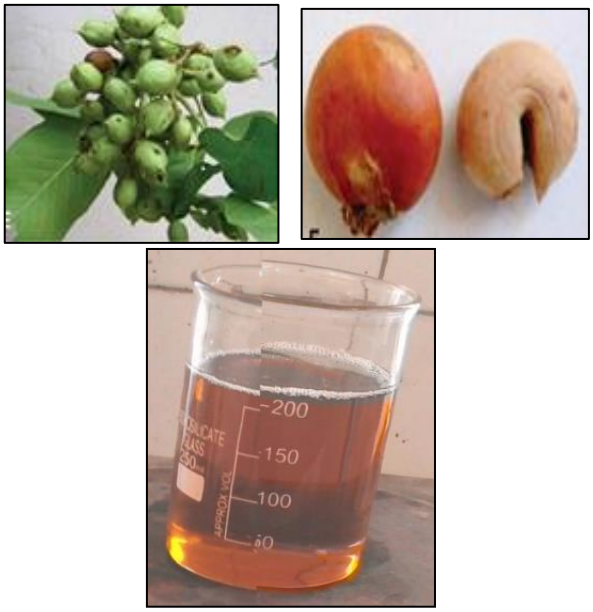


Figure 1. Picture of Kusum,leaves, seeds and oil

Kusum oil +Alcohol = Kusum biodiesel +Glycerin (1)

Experimental

Amount of Kusum oil, methanol and catalyst used during the production process at different molar ratio(s) of alcohol to the triglyceride or specimen oil is shown in Table 2. However, during the all molar ratio(s) the amount of acid catalyst (H_2SO_4) consumed was kept same i.e. 1% of the specimen oil. The stoichiometrically requirement for transesterication is 3 mole of the alcohol per mole of the triglyceride to yield 3 moles of the fatty esters and 1 mole of the glycerol. However, in practice an excess amount of alcohol is taken to drive the reaction close to completion in a forward direction. Table 3 gives the yield at different reaction times, molar ratio (s) and catalyst (KOH) percentage.

Table 2. Amount of Kusum Oil, methanol, catalyst used during experiment and 1% acid

Molar ratio	Kusum oil (g)	Methanol (g)	Pretreated oil (g)	Catalyst (g)		
				0.5wt %	0.75wt %	1.0wt %
4.5:1	500	85	421	2.1	3.1	4.2
6:1	500	110	405	2.25	3.3	4.5
9:1	500	166	465	2.32	3.4	4.65

Table 3. Yield vs. Reaction Time at Different Molar Ratio(s) & Catalyst (KOH) Percentage

Percentage Catalyst	Molar ratio 4.5:1		Molar ratio 6:1		Molar ratio 9:1	
	Reaction Time (min)	Yield (%)	Reaction Time (min)	Yield (%)	Reaction Time (min)	Yield (%)
0.5wt%	30	57.97	30	63.16	30	77.82
	45	61.45	45	68.52	45	80.19
	60	65.63	60	71.77	60	84.37
	75	63.50	75	67.98	75	82.51
	90	62.57	90	67	90	81.29
0.75wt%	30	58.62	30	64.16	30	79.52
	45	62.39	45	69.52	45	82.76
	60	66.89	60	72.77	60	88.53
	75	64.33	75	69.68	75	87.45
	90	63.28	90	67.89	90	85.61
1.0wt%	30	59.56	30	66.12	30	83.07
	45	63.52	45	71.61	45	85.26
	60	68.09	60	73.7	60	91.25
	75	67.12	75	71.49	75	88.72
	90	65.43	90	70.72	90	86.43

RESULTS AND DISCUSSION

Physico-chemical properties of Kusum seed oil

Various physico-chemical properties of Kusum oil and its bio- diesel were determined according to standard methods. Table 4 presents the average values of the physico-chemical properties of Kusum bio- diesel, diesel and their blends. Table 4 shows that the density of KOME was found to be 0.87g/, which is closer to the density of diesel. The flash points of KOME were 152^0C, which is higher than the fossil diesel. Higher flash point of KOME ensures safe handling and storage. The calorific value of *Prunus armeniaca* biodiesel obtained in the present study (39.45 MJ/Kg) is quite comparable with the conventional diesel. As fuel properties of the produced biodiesels were within the recommended limits according to the ASTM/EN standards, hence, *Prunus armeniaca* biodiesel can be used as an alternate fuel without any modification of the diesel engines.

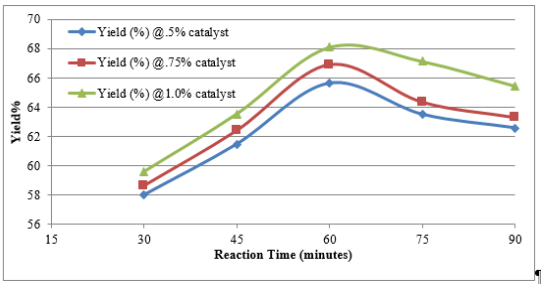
Biodiesel yields

Biodiesel yield at different molar ratio, reaction time and temperature is shown in Figure 2(a) to 2(d). From Figure 2(a) it was observed during the reaction with a molar ratio of 4.5:1; maximum yield of 68.09% for the reaction time of 60 minutes and 1% catalyst was obtained. In addition, for the lower weight of catalyst (0.5 and 0.75%) at the same reaction time, yields were 71.77 and 72.77 %, respectively. When the molar ratio increase to 6:1, maximum yield of 73.70% for 60 minutes reaction time and 1% of catalyst was obtained. In contrary, for 0.75 and 0.5% catalyst at the same reaction time the yields were 66.89 and 65.63%, respectively (see Figure 2 (b)). It was reported that at molar ratio of 6:1 or higher generally gives the maximum yield (higher than 98%) and lower molar ratios take a longer time to complete the reaction [7, 12-14]. However the reaction yield may be different for the case of high FFA oils. While increasing the molar ratio of 9:1 it was observed that the maximum yield of 91.25% was obtained for 60 minutes reaction time and 1% of catalyst. However, for the same time period the yield slightly decrease to 88.53 and 84.37% for 0.75 and 0.5% catalyst respectively. The obtained data are shown in Figure2 (c). Figure 2(d) shows the comparison for

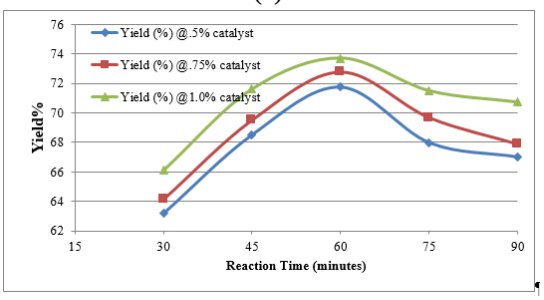
Table 4. Physico-chemical properties of Kusum biodiesel and mineral diese

Properties	Kusum Oil	KOME	Diesel	Testing Method	ASTM D6751 Limit of Acceptance	EN 14214 Limit of Acceptance	Measurement Apparatus
Density at 15^0C (g/ml)	0.88	0.87	0.82	ASTM D1298	0.88	860–900	Stabinger Viscometer-SVM 3000 (Anton Paar India Pvt. Ltd.)
Viscosity at 40^0C (cSt)	41.2	4.7	2.956	ASTM D445	1.9–6.0	3.5–5.0	Stabinger Viscometer-SVM 3000
Flash point (^{0}C)	223	152	61	ASTM D 92	Min. 130	Min. 120	Pensky-Martens closed cup apparatus
Fire point (^{0}C)	229	156	63	ASTM D 92	-	-	Pensky-Martens closed cup apparatus
CFPP (^{0}C)	-	- 4.0	-8	ASTM D 6371	Max.19	-	Automatic NTL 450 (Normalab, France)
Calorific value(MJ/kg)	37.8	39.45	43.32	ASTM D240	-	-	Parr 6100 calorimeter (IKA, UK)
Oxidation Stability (h)	-	>6.5	-	EN 14112	-	Min. 3	873 Rancimat (Metrohm, Switzerland)

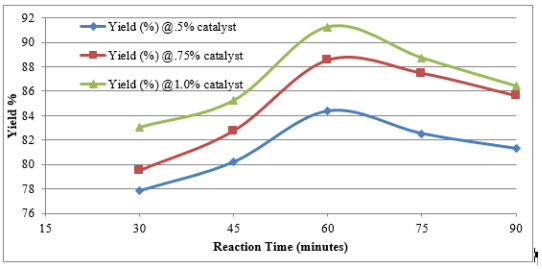
yield obtained at different reaction time, molar ratios and catalyst percentages. It is worth to mention here that the excess molar ratios increase the conversion rate but leads to difficulties in the separation of the glycerol which was observed when a molar ratio of 12:1 was experimented. At optimum molar ratio only the process resulted high yield and easily separation of the glycerol. Hence it can be stated that the optimum molar ratios depend on the type and quality of the vegetable oil used as in the case of Kusum oil specimen, we have taken for study.



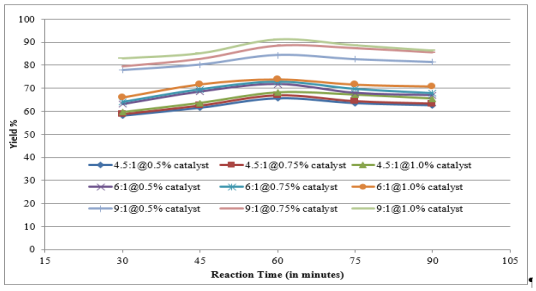
(a)



(b)



(c)



(d)

Figure 2. (a) Yield Vs. Reaction Time at 4.5:1 Molar Ratio, (b) Yield vs. Reaction Time at 6:1 Molar Ratio, (c) Yield Vs. Reaction Time at 9:1 Molar Ratio, (d) Comparison for Yield vs. Reaction Time at Different Molar Ratio(s) & Catalyst (KOH) Percentage

CONCLUSION

From the present research work can be concluded that KOME is one of the potential feedstock for biodiesel production. In this study, esterification was carried out as pre-treatment for the feedstock followed by transesterification process. Biodiesel production from KOME was conducted using transesterification process and the highest yield of KOME obtained was 91.25% for 60 minutes reaction time, 9:1 Molar ratio and 1% of catalyst concentration. Characterizations of KOME according to international standard method (ASTM D6751 and EN 14214) showed that the properties of KOME meet the standards.

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Persian Abstract

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