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Production, optimization and quality assessment of biodiesel from *Ricinus communis* L. oil

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ABSTRACT

At present, biodiesel is gaining tremendous attention due to its eco-friendly nature and is possible substitute for diesel fuel. Biodiesel as renewable energy source can be produced from edible and non-edible feedstock. Non-edible resources are preferred to circumvent for food competition. In the present study FAME was produced from *Ricinus communis* L. oil by transesterification with methanol and ethanol in the presence of potassium hydroxide. The practical optimal condition for the production of biodiesel from castor bean was found to be: methanol/oil molar ratio, 6:1; temperature, 60 °C; time, 45 min; catalyst concentration 0.32 g. Quality assessment of biodiesel showed comparable results with ASTM standards. The values of specific gravity (SG) were 0.5, kinematic viscosity 2.45 cSt, acid values 0.13 mg KOH/g, carbon residue 0.03%, flash point 119 °C, fire point 125 °C, cloud point −10 °C and pour point −20 °C of Ricinus FAME, respectively. Based on our data, it is suggested that to overcome prevailing energy crisis this non-edible plant is useful for production of biodiesel, which is an alternate to fossil fuel and may be used alone or in blend with HSD in engine combustion.

1. Introduction

Biodiesel is a renewable alternate source of petroleum and can be used in engine. It is eco-friendly, nontoxic and it is thought to be future diesel. Petroleum is natural source that is rapidly depleted. Biofuel is obtained from vegetable oil, algae, edible and non-edible beans like, Helianthus, Jatropha, Pongamia and Ricinus. It is derived from triglycerides and fatty acids by transestrification and esterification, respectively (Bari, Yu, & Lim, 2002).

Fossil based petroleum is not renewable stored in earth with limited reserves. World heavily depends on petroleum for transport vehicles, industrial and agricultural machinery. Increase in population, industries and urbanization causes of increase in fuel combustion. It leads to removal of petroleum fuel from earth reservoirs. This higher expenditure will lead to industrial catastrophe. In cities, air contamination increases because diesel engine is a big pollution source by traffic in urban areas. Carbon monoxide and carbon dioxide are rapidly increases and many other gasses from smoke are releases.

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Oxides of carbon and nitrogen causes headache, low blood pressure, acute bronchitis, pulmonary diseases and throat problems. Because of air contamination many respiratory diseases are causes in animals and also harmful for plants. Now societies are aware about air pollution caused by diesel engine, so pressure on researchers to search alternate way of diesel to reduce environmental pollution (Atadashi, Aroua, &Aziz, 2010). At the present time, the world demand of energy rapidly increasing because of increasing population, industrialization, and over urbanization (Vasudevan & Briggs, 2008).

As increase in consumption of oil emission of pollutants increases, it will affect human health badly such as respiratory, skin, and nervous system. Increasing population and over urbanization causes energy crisis, because of energy crisis biodiesel from non-edible oil-seeds are highly in concern as alternate source of petroleum. It is non-toxic, biodegradable, renewable source, eco-friendly and cause reduction in use of petroleum. Carbon that is released from burning will use by plants, enhances the life of engine, no change in engine by its use enhances rural economics. Biodiesel prepared directly from fat of animal and oil from seeds of plants by transestrification method using alcohol and catalyst (Hazell & Pachauri, 2006).

2. Material and methods

For the present research, *Ricinus communis* L. seeds were purchased from Makah Traders Pasroor, Sialkot, Punjab, Pakistan. Determination of oil or fat content from seeds has great importance on industrial scale as it effects price of raw material. Soxhlet apparatus gives oil content extracted from solid source. Damirchi, Habibi-Nodeh, Hesari, Nemati, & Achachlouei, 2009 protocol of soxhlet apparatus was followed. In order to get massive quantities of oil, electrical oil expeller was used. Then, oil was filtered with help of filter paper. After filtration titration was done to measure free fatty acid contents in it.

2.1. *Pre-tests for Ricinus oil*

In pre-tests oil quality was measured such as acid value, gravity, density, saponification and viscosity, refractive index and peroxide value. These tests were used to find out oil quality (Patil and Deng, 2009). Physical characterization of *R. communis* was carried out according to the methods given in association of analytical chemistry (AOACS).

2.2. *Transesterification*

Transesterification is a process in which conversion of fatty acid methyl ester from crude oil occurs (Ahmad, Khan, Zafar, Sultana, & Gulzar, 2009). Oil from plants is esters of triglyceroides. During alcoholysis, triglyceroides is converted into di and then in monoglyceroids. On each step it needed 1 mol of fatty acid but in experiment greater amount of alcohol added because it is a reversible reaction (Dennis, Wu, & Leung, 2009). Alkali alcoholysis is existing method that is frequently using for production of biodiesel, Sinha, Agarwal, and Garg (2008); Meher, Vidya Sagar, and Naik (2006); Ahmad et al. (2010). Ma and Hanna (1999) stated that in transesterification butanol, propanol, methanol, amyl alcohol and ethanol any alcohol can be used and used alkali catalyst. Methanol is mostly used because it is cheap and it has chemical and physical advantages. It can easily react with alkali catalyst.

In transesterification, after filtration crude filtered oil was heated in order to breakdown of triglycerides into di and mono-glycerids and to remove free fatty acids from filtered oil. It was heated on hot plate (VWR, VELP- Scientifica Germany) at 100 °C for 1 h till oil temperature became 120 °C, and then left it on room temperature to cool until 60 °C. Then mixture of methanol and KOH and NAOH were added to heated oil separately to find out the maximum FAME production.

Then it was stirred at 600–700 rpm for 45 min at 60 °C. Stirring time and temperature has direct effect on ester yields. It was left to settle down on room temperature for 1 h to overnight. Three layers were formed upper layer was thin soap layer, second layer was methyl/ethyl ester, third layer was glycerol. Glycerol and soap were by product of transesterification. Distilled hot water was used to purify crude methyl/ethyl ester. Water amount was lowered to maximum of 0.05% according to ASTM standard of biodiesel (v/v). This step was repeated 3–4 times. In order to neutralize soap and residual catalyst, washing was done at pH 4.5, Du, Xu, Liu, Zeng, and Molcatal (2004). Then Na_2SO_4 was added to prepared biodiesel in order to remove water.

2.3. *Optimization*

Optimization is a process in which different trail applied with variables of temperature, methanol to oil ratio, time and catalyst to examined variable effects on yield (%) were noted. Optimization was done to attain the maximum ester yield.

2.4. *Fuel properties*

Fuel properties of Ricinus FAME are presented in Table .1 and results were matched with ASTM.

3. Results and discussion

Biodiesel is non-toxic, free of sulfur, renewable and alternative green fuel. Commonly it is produced by transesterification reaction of non-edible oil, vegetable oil and waste oil using small amount of alcohol as methanol or ethanol. Its demand is rather high to produce as alternative energy sources, because availability of fossil based petroleum is rapidly decreasing. Biodiesel is a potential substitute of energy because it is obtained from renewable energy sources. In the current study, biodiesel was extracted from castor. Oil percentage was in *R. communis* 48%.

3.1. *Characterization of oil*

Oil percentage was from *R. communis* 48. For physicochemical characterization oil qualities were measured such as acid

Table 1 – Optimization effects on product yield (biodiesel, glycerol and soap) of *Ricinus communis*.

Sr.#	Oil conc.	Optimization					Results products yield		
		Methanol to oil ratio	Catalyst concentration		Reaction time (min)	Reaction temp. (°C)	Biodiesel (gm)	Glycerol (gm)	Soap (gm)
			KOH (gm)	CH_3OH (gm)					
1	50	4:1	0.32	5	70	60	42.5	2.40	1.7
2	50	5:1	0.32	10	70	60	45.0	2.0	1.45
3	50	8:1	0.32	15	70	60	37.50	7.06	2
4	50	5:1	0.32	10	60	60	23.2	2.35	4.10
5	50	5:1	0.32	10	70	60	40.05	3.98	2.5
6	50	5:1	0.32	10	80	60	43.5	2.4	0.89
7	50	5:1	0.32	10	70	45	20.0	2.25	5.20
8	50	5:1	0.32	10	70	60	42.0	3.45	2.90
9	50	5:1	0.32	10	70	80	25.5	6.78	4.8
10	50	5:1	0.25	10	70	60	23.5	3.05	2.5
11	50	5:1	0.32	10	70	60	44.5	2.0	1.5
12	50	5:1	0.40	10	70	60	28.5	3.0	0.98

value, gravity, saponification, viscosity, refractive index and peroxide value (Patil & Deng, 2009).

3.2. *Acid value*

The data revealed that 0.9 mg KOH/g were acid values of crude oil Ricinus. FAME of castor was having 0.3 mg KOH/g acid value (Table 2). These were compared with biodiesel standard ASTM D 664 and were found in range of standards. According to this standard 0.8 was maximum acid value of biodiesel. Therefore, our results were closed to Patil and Deng (2009) results, who reported A.V. value 0.61 and 0.76 for jatropha.

3.3. *Peroxide value*

It is a test used to determine oil oxidative rancidity or fats measured occurrence of lipid peroxides. Determined value of oil was 5.5 (Table 2).

3.4. *Specific gravity*

Specific gravity was 0.9 of castor and methyl ester of castor was 0.5. Our results were in range of ASTM D 675 10-02 (Table 2). Patil and Deng (2009) reported that values of canola, jatropha and karanja methyl ester specific gravity were 0.88, 0.89 and 0.86–0.88 in order.

3.5. *Refractive index (R.I.)*

Refractive index values were 1.43 of castor crude oil (Table 2). Our result was much close to 1.47 of rapeseed and castor oil order as reported by Saqib et al. (2012) and Hlaing et al. (2008).

3.6. *Saponification value*

Saponification value was 170.73 mg KOH/g of castor and crude oil (Table 2). Wang et al. (2011) reported that saponification value 191.23 mg KOH/g of *Jatropha crucas* that was in line with our results.

3.7. *Optimization through transesterification*

Variable applied during transesterification i.e. reversible and successive numbers of reactions (Du et al., 2004). Following were our results of transesterification.

3.7.1. *Effect of temperature on biodiesel production*

Ricinus at 45, 60 and 80 °C were testified and FAME yield was 84% at 60 °C (Table 1) of castor (Fig. 1). Agarwal et al. (2001), and Dorado et al. (2004) reported that using alkaline catalyst in transesterification temperature effected its yield. With increased temperature (°C) from optimum point biodiesel yield decreased. Xuan et al. (2011) reported that at 60 °C

Table 2 – Fuel properties of crude oil and FAME of *Ricinus communis*.

Fuel properties	Crude oil	ASTM biodiesel standard	HSD	Biodiesel
Sample	Castor			Castor
Refractive index	1.436	ASTM D 960-79	1.32	–
Saponification (mg KOH/g)	170.73	–	–	–
Peroxide value	5.5	–	–	–
Cloud point	–	ASTM D975-98	2.0 °C	−10 °C
Pour point	–	ASTM D6751-02	−7 °C	−20 °C
Flash point	–	ASTM D975	60–80	119 °C
Fire point	–	ASTM D975	78	125 °C
Specific Gravity	0.9	ASTM D6751-02	0.87–0.90	0.5
Ash point	–	ASTM D 524	0	0.03%
Kinematic Viscosity cSt	25	ASTM D6751	1.9–6.0	2.45
Acid value mg KOH/g	0.9	ASTM D 664	0.8 max	0.13

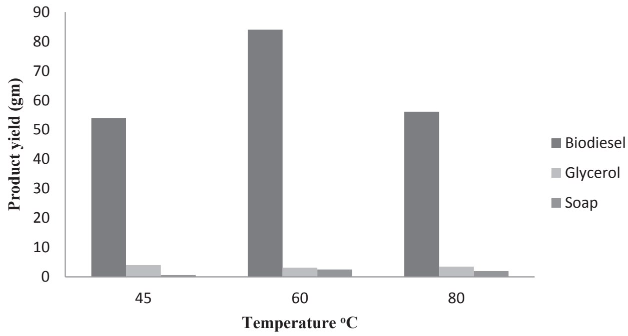

Fig. 1 – Effect of temperature on product yield (biodiesel, glycerol and soap) of *Ricinus communis*.

temperatures biodiesel yield was maximum from camelina oil.

3.7.2. *Effects of catalyst on biodiesel production*

Variable catalyst trial gave different results on different amount. Variable amount were 0.25, 0.32 and 0.40 g (Table 1). Biodiesel yields 90% were obtained with 0.32 g amount of catalyst of castor as shown in (Fig. 2). Meher et al. (2006) reported that alkali catalyst amount effected on biodiesel yield in karanja and jatropha oil.

3.7.3. *Effect of reaction time on biodiesel production*

Experiments were done within different time points (60, 70 and 80 min) to estimate the effect of time on transesterification reaction. With increasing time, product yield also increased within 70 min 90% (Fig. 3). Relatively higher yield of biodiesel was obtained from castor (Table 2). Fukuda et al. (2001); Freedman et al. (1984) and Metsovitia et al. (2013) reported that for best results of transesterification the stirred time should be constant. However, non-edible oil stirred time was variable from 30 min to 150 min, but further increased in time duration decreased the product yield because of reversible reaction. Our results were similar to findings of Xuan et al. (2011) in which within 70 min, highest biodiesel was obtained from camelina oil.

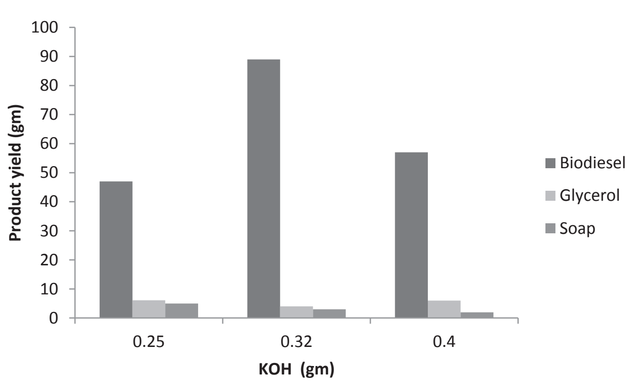

Fig. 2 – Effect of KOH catalyst on product yield (biodiesel, glycerol and soap) of *Ricinus communis*.

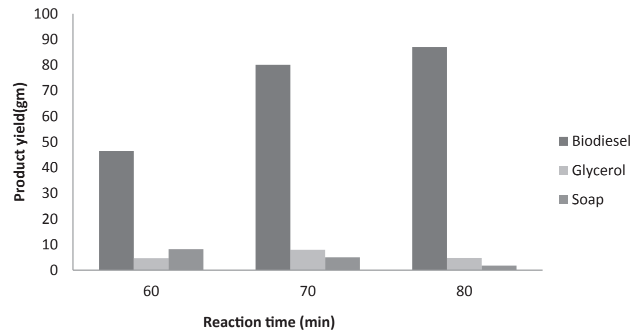

Fig. 3 – Effect of time on product yield (biodiesel, glycerol and soap) of *Ricinus communis*.

3.7.4. *Effects of methanol to oil ratio on biodiesel production*

Transesterification of Ricinus oil was carried out on different oil alcohol ratio (4:1, 5:1, and 8:1) (Table 2). From castor with 5:1 (methanol to oil ratio), 90% yield (Fig. 4). Our results are similar to the findings of Sanford et al. (2009) and Ahmed et al. (2008), using methanol to oil ratio (6:1) from karanja, castor oil and from other vegetable oils, biodiesel yield was 94%.

3.8. *Fuel properties*

Investigation for different fuel properties were carried out *e.g.* carbon residue, fire point, flash point and cloud point (Table 2). Results showed that flash point was 119 °C of Ricinus (Sinha et al., 2008; Karmee and Chadha, 2004; Demirbas, 2011) results were similar as flash point 126 °C of biodiesel of vegetable oil. Saxena, Jawale & Joshipura (2013) reported that flash point range of biodiesel from vegetable oil was 420–450 °C. Fire point is the temperature near but greater than flash point, where oil catches fire. Biodiesel fire point was 125 °C of Ricinus (Table 2). Raja et al. (2011) reported that fire point was 256 °C of jatropha and 136 °C of biodiesel of jatropha. Cloud point of Ricinus was −10 °C and pour point was near cloud point −15 °C and (Table 2). Sinha et al. (2008); Ahmad et al. (2009) reported that cloud point of biodiesel from vegetable oil varies from 2 to −60 °C. Kinematic viscosity of *R. communis* was 2.45 cSt (Table 2). Our result was much closer to 3.14 and 4.57 cSt of diesel and biodiesel kinematic viscosity from

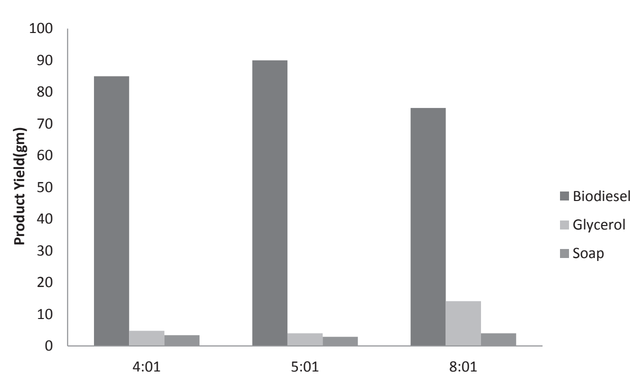

Fig. 4 – Effect of methanol to oil ratio on product yield (biodiesel, glycerol and soap) of *Ricinus communis*.

vegetable oil, as reported by Guido et al. (2013) and Yilmaz et al. (2013). Saqib et al. (2012) found rapeseed biodiesel K.V. 4.42 (mm^2/sec) that is in line with our results. Saxena et al. (2013) reported that kinematic viscosity of biodiesel from vegetable oil was 3.2–3.5 cSt.

4. Conclusion

Based on data it is concluded that high yield obtained from *R. communis* under optimum conditions. Using alkaline catalyst, KOH gave best results as compared to NaOH catalyst. In alcohol catalyst from CH_3OH obtained high yield of biodiesel as compared to CH_2OH under optimum conditions. Characteristics of biodiesel obtained from *R. communis* were comparable with commercially used diesel in engine for combustion. The biodiesel could be used alone or blend with commercial diesel. This may ensure to be eco-friendly and safe for environment. Results revealed that after conversion of oil into FAME it can be used as alternate of fossil based fuel to overcome energy crisis.

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