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A Comprehensive Analysis of Fuel Properties of Biodiesel from *Koroch* Seed Oil

Anil Kumar Sarma,* D. Konwer, and P. K. Bordoloi

Department of Energy, Tezpur University, Napaam-784028, Assam, India

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Introduction

Biodiesel production and application are gaining popularity in recent times due to diminishing petroleum reserves and detrimental environmental impacts. Edible and nonedible oils are transesterified in the presence of alcohol and a suitable catalyst to prepare the esters of the corresponding alcohol, commonly used as biodiesel. However, biodiesel, because of having a narrow range of boiling points, often requires blending with petroleum diesel.^{1,2} In this study, biodiesel production from a variety of *Pongamia glabra* called “*Koroch*” oilseeds collected from the Darrang District of Assam, India, has been reported. The systematic analysis of the fatty acid composition along with a comparative analysis of the fuel properties of biodiesel with petroleum diesel oil has also been reported. A Sim-Dis gas chromatography (GC) analysis has also been carried out to determine accurately the IBP/ FBP and distillation characteristics, to show the prospect of blending with the lower boiling distillation cut of petroleum crude oil so as to mitigate the demand of low-sulfur high-speed diesel.

Experimental Section

Properties and Composition of the Oil. *Koroch* is a leguminosae, subfamily papilionoideae, middle-sized tree grown in plain humid regions of Assam, lower parts of Meghalaya, Nagaland, and Northern Bengal in India. It bears a seed usually harvested within the period from December to March every year. About 30 kg of seed were collected from about a 15-year-old tree and dried at 50 °C for 72 h and then shelled and milled. The oil was extracted from the milled kernels with petroleum ether (40–60) °C using the Soxhlet extraction method,³ and the oil content was also determined by the Soxhlet extraction method,⁴ which was found to be 33.6% by weight of the milled kernel. The oil is pale yellow in color and is nonedible. The major properties from proximate analysis of the oil were determined and reported in Table 1. The fatty acid composition of the oil was determined by GC using the AOCS Official method 1998, Ce 1–62 and Ce 2–26, and has been reported in Table 2. The results obtained ensure that 26% of the oil is saturated fatty acids, 45% unsaturated acids with one double bond, and 25% unsaturated acids with two double bonds, while a maximum of only 3% are the unsaturated acids with three double bonds. Only 1% of the oil component could not be identified. A distinct variation of the fatty acid composition has been observed as reported for *pon-gamia glabra* oil³ that reveals the unique features of *Koroch* seed oil as a potential source for biodiesel production. Thus, 99%

Table 1. Properties from Proximate Analysis of *Koroch* Seed Oil

property	value
density at 15 °C	0.931 g/cm ³
pour point	0 °C
kinematic viscosity at 40 °C	26.060 cst
acid value	7.510 mg KOH/g
ash	0.001 wt %
Conradson carbon residue	1.205 wt %
calorific value (gross)	42.510 kJ/g

Table 2. Fatty Acids Composition of *Koroch* Seed Oil

fatty acid	molecular formula	composition (wt %)
palmitic	C ₁₆ H ₃₂ O ₂	11.30
stearic	C ₁₈ H ₃₆ O ₂	9.80
oleic	C ₁₈ H ₃₄ O ₂	45.25
linoleic	C ₁₈ H ₃₂ O ₂	24.75
linolenic	C ₁₈ H ₃₀ O ₂	2.90
srachidic	C ₂₀ H ₄₀ O ₂	1.75
behenic	C ₂₂ H ₄₄ O ₂	3.20
unidentified		1.05

conversion could be expected to the corresponding esters of the respective triglycerides.

Biodiesel Production. The production was carried out in a 2-L capacity glass vessel equipped with a mechanical stirrer, funnel, and a condenser placed in a water bath having a proportional integral derivative temperature control device. *Koroch* seed oil (500 mL) and 150 mL of methanol (98% pure) were mixed (in 1:6 molar ratios), and the mixture was placed inside the reactor. The alcohol was mixed initially to ensure proper mixing with the oil and to overcome subsequent evaporation losses. The temperature was raised to 60 °C, and the mixture was stirred at 600 rpm. When the mixture temperature reached 60 °C, 4.5 g (1% by weight of the oil) of freshly prepared sodium methoxide was added to it. Thus the reaction was continued for 1 h, an optimum reaction time, as determined from three sets of experiments conducted initially for 0.5-, 1-, and 1.5-h durations. As soon as the reaction time was over, the mixture was placed in a separator funnel and allowed to cool for 2 h. Two distinct layers were found to form, the upper layer being the methyl ester and the lower layer glycerol. A rotary evaporator coupled to a vacuum pump was used to recover the unreacted alcohol from the ester layer. The unreacted alcohol (30 mL) was recovered. The ester was then washed twice with distilled water. The emulsified water was removed through a rotary evaporation method. Biodiesel (488 mL) and 32 mL of glycerol were recovered by this method. The transesterification reaction was rapid, and layer separation from glycerol was much easier compared to many other triglycerides.^{1,2} This is attributed to lower percentage of high olefin triglycerides present in the oil. Lower is the percentage of olefin present better is the transesterification.

Results and Discussion

Comparative Fuel Properties of Biodiesel and Petroleum Diesel. The biodiesel so prepared and the low sulfur petroleum diesel collected from Numaligarh Refinery, Assam, India, were tested for all the fuel properties using standard ASTM methods,⁵ and the

* Author to whom correspondence should be addressed. E-mail: anil_tu@yahoo.co.in.

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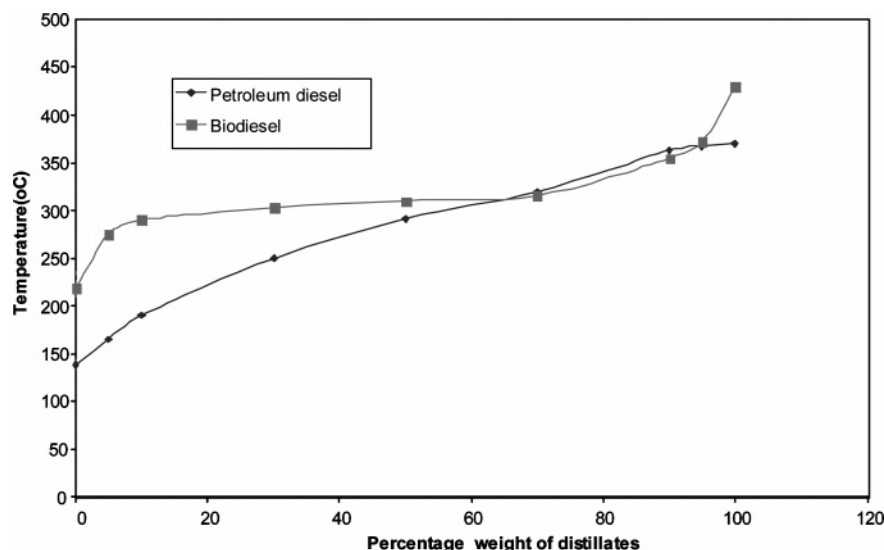


Figure 1. Sim-Dis GC distillation analysis of biodiesel from *Koroch* seed oil and petroleum diesel.

Table 3. Properties of Biodiesel (Methyl Ester) Prepared from *Koroch* Seed Oil and Petroleum Diesel Obtained from Numaligarh Refinery (Assam)

property	Value	
	100% petroleum diesel	100% biodiesel (methyl ester)
density at 15 °C	0.852 g/cm ³	0.903 g/cm ³
kinematic viscosity at 40 °C	2.781 cst	6.130 cst
water content	0.055 vol %	0.450 vol %
Conradson carbon residue	0.100 wt %	0.781 wt %
cetane number	46	55
pour point	0 °C	+3 °C
flash point	49 °C	95 °C
gum content	0.010 g/100 mL	0.150 g/100 mL
sulfur content	0.017 wt %	0.005 wt %
copper strip corrosion	1a	1a
ash content	0.010 wt %	0.001 wt %
IBP/FBP	139/370 °C	219/430 °C
calorific value	45.013 kJ/g	43.422 kJ/g
acid value	0.104 mg KOH/g	0.000 mg KOH/g

results are presented in Table 3. The biodiesel had a color (pale brown) very similar to petroleum diesel. A comparative study of the physicochemical properties of this biodiesel with the low-sulfur diesel made it evident that the density, viscosity, and carbon residue values are higher than the acceptable ranges. High flash point and higher cetane number, however, are good indications from the viewpoint of auto-ignition and improvement of knocking properties. Calorific value is comparable, while sulfur and ash contents are lower, indicating good fuel properties. Sulfur was found to be three times lesser in biodiesel compared to that in petroleum diesel, which is attributed to the reduction of SO₂ emission on combustion, finally unveiling the environmental benefits. Higher moisture content reduces the heat value during combustion and is a cause of serious concern for corrosive effects in engine parts, in combination with SO₂. However, these can be eliminated by the application of proper drying methods before end uses.

Distillation Characteristics. The distillation (volatility) characteristics of hydrocarbons have immense implication on the engine performance and safety. Volatility is the major determinant of the tendency of a liquid fuel to produce potentially explosive vapor and proper air fuel mixture. The presence of high boiling point components

can significantly affect the degree of formation of solid combustion deposits. The Sim-Dis GC distillation characteristics depict the percentage recovery of biodiesel and petroleum diesel at different temperature regions as shown in the Figure 1. It indicates that the biodiesel has a narrow boiling range 219–430 °C, 95% of which was boiled off between 219 and 372 °C while petroleum diesel has a uniform boiling range of 139–370 °C. The IBP value of petroleum diesel was 139 °C, while for biodiesel it was 219 °C. This implies that there is a shortage of around 25% lower boiling cut hydrocarbon (below 220 °C) in biodiesel. Similarly the steeply rising portion from 350 to 370 °C indicates the shortage of about 10% long-chain hydrocarbon in biodiesel to achieve similar distillation properties such as the petroleum diesel. Another 15% hydrocarbon may be added within the boiling range of 220–300 °C to make the distillation curve equivalent. Thus it is observed that 50% i.e. (25 + 15 + 10)% hydrocarbon fell short in biodiesel to achieve similar distillation properties such as petroleum diesel.

Conclusion

The blending of biodiesel with the lower boiling cut of petroleum distillates has dual advantages. First, these may be obtained from atmospheric distillation of petroleum crude oil alone, which can save a major part of energy input to the vacuum distillation unit. Second, the blending will sharply bring down the values of properties of biodiesel such as specific gravity, viscosity, and carbon residue to acceptable ranges and would improve the atomization process during combustion. However, an additional distillation may be employed to remove the much heavier distillation cut above 372 °C of *Koroch* biodiesel, which is primarily responsible for carbon-residue deposition. Thus it is expected that 50% blending of petroleum distillates with this biodiesel will be realistically possible after the completion of the ongoing investigation.

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