Asian Journal of Chemistry Vol. 18, No. 4 (2006), 2951–2958

Production and Evaluation of Biodiesel from Sunflower (*Helianthus annus*) and Nigerseed Oil (*Guizotia abyssinica*)

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Various vegetable oils have been explored to make biodiesel (long chain fatty acid alkyl esters) in order to substitute/supplement the dwindling supplies of conventional diesel fuels. In the present study, Sunflower oil (*Helianthus annus*) and Nigerseed oil (*Guizotia abyssinica*) were transesterified with methanol using sodium hydroxide as catalyst to produce biodiesel. Blends of varying proportions of biodiesel and diesel were used to run a 4-stroke single cylinder internal combustion engine and significant improvements in engine performance and emission characteristics were observed. The results of these investigations clearly indicated that the partial substitution of diesel oil with biodiesel could be achieved with better performance and lower emission levels. This not only results in considerable economy but also decreases the usage of non-renewable and ecofriendly fuel.

Key Words: Biodiesel, Sunflower oil, Nigerseed oil.

INTRODUCTION

Vegetable oils have long been suggested as promising candidates for alternative diesel fuels[1–5]. But their high viscosities, low volatilities and poor cold flow properties prevent them from being used as an alternative diesel fuel[6–8] .The fatty acid methyl esters, commonly known as 'Biodiesel' have been suggested as alternative diesel fuels compared to non-edible oils. Krishnan *et al.*[9] reported the performance of conventional diesel engines operated on biodiesel. They observed reduction in hydrocarbon and carbon monoxide emission and slight increase in NO emission in comparison to conventional diesel fuels.

Diesel engines play a vital and indispensable role in today's modern life and at the same time contribute to pollution substantially. The threat from environmental degradation endangers the quality of life in modern society and jeopardizes the continual global development. One solution to avoid the twin problem of environment pollution and energy shortage will be a carefully planned gradual shift of our energy economy from fossil fuels to renewable sources of energy[10].

The use of alternate fuels without engine modifications would also immediately strike a chord with the common man. For the developing countries, the use of fuels of biological origin may prove advantageous[11]. In this context, the various bio-origin fuels that can be used are alcohol, edible and non-edible vegetable oils, biomass, biogas, etc. The latest to join the league is "Biodiesel". Biodiesel is renewable, as supplies of the raw materials required for biodiesel production can be replenished by the growth of plants or production of livestock.

EXPERIMENTAL

The apparatus used for transesterification consisted of a 3-necked round-bottom flask of suitable capacity with provision for the introduction of a condenser and thermometer pocket. An electric heater with magnetic stirring mechanism was used which accomplishes the function of heating as well as stirring. The experiment was carried out in the following series of steps:

Activation of alcohol: The first step was the activation of alcohol by dissolving the catalyst sodium hydroxide in alcohol to form the corresponding alkoxide. Methanol and sodium hydroxide were stirred vigorously in a closed vessel until alkali dissolved. Here, care was taken to protect the mixture as much as possible from carbon dioxide and water, both of which destroy the catalyst.

Reaction: The alcohol/catalyst mixture was then changed into a closed vessel and the oil was then added such that oil : methanol ratio was 10 : 1 by weight. The reaction mixture was kept at 70°C (*i.e.*, just above the boiling point of alcohol) to speed up the reaction. The reaction was carried out for 1 h.

Separation: After completion of the reaction, the products: methyl esters (biodiesel) and glycerol, were allowed to settle by gravity in a separating funnel. Glycerol being denser settles down, while biodiesel forms the upper layer. The two layers are separated. Each layer contains some amount of methanol that has to be removed.

Glycerol purification: The excess alcohol from glycerol layer can be removed by distillation. The recovered alcohol can be re-used. The glycerol by-product contains unused catalyst and soaps that are neutralized and pharmaceutical grade glycerol can be obtained by a series of purification steps.

Methyl ester wash: The methyl ester also contains unused catalyst and methanol, both of which have to be removed. The methyl ester was first neutralized with sulphuric acid (30%) to deactivate the catalyst. It was then washed with hot water to remove the catalyst. The washing was continued until pH of the wash water was in the range of 6–7. The washed ester was then dried using silica gel. Methanol was removed by distillation. Details of reactants and products involved are given in Table-1.

Analysis of biodiesel: The various fuel properties of the biodiesel produced by transesterification were determined experimentally to ascertain its suitability as diesel fuel. The various properties that were determined were viscosity, density, acid value, saponification value, flash point, fire point and calorific value.

Characteristics of sunflower, nigerseed and their methyl esters are shown in Table-2. Comparison of the properties of biodiesel and diesel are shown in Table-3. Fuel properties of different blends of biodiesel with diesel are shown in Table-4.

TABLE-1
DETAILS OF REACTANTS AND PRODUCTS INVOLVED

Reactants	Quantity (g)	
	Sunflower oil	Nigerseed oil
Vegetable oil	360	300
Methanol	36	30
Sodium hydroxide	1.8	1.5
Products:		
Methyl esters	347	295.50
Glycerol	27	30
Methanol recovered	7	–
Yield of methyl esters (based on vegetable oil wt %)	96.38	98.50

TABLE-2
CHARACTERISTICS OF SUNFLOWER, NIGERSEED AND THEIR METHYL ESTERS

S.No.	Characteristics	Vegetable oil		Methyl esters of	
		Sunflower	Nigerseed	Sunflower	Nigerseed
1.	Density	0.9126	0.9061	0.8870	0.8966
2.	Viscosity (cp)	41.2110	35.2000	7.49	7.60
3.	Kinematic viscosity (cst)	45.1570	–	8.45	8.40
4.	Acid value (mg KOH/g)	2.6603	3.0200	1.7994	1.4000
5.	Saponification value	186	80.52	173	192.1
6.	Flash point (°C)	–	–	174	188
7.	Fire point (°C)	–	–	190	215
8.	Carbon residue	–	–	1.69	6
9.	Calorific value (kcal/kg)	–	–	15,553	12,282

Engine test: Performance appraisal by testing with diesel engine: Two sets of blends were prepared. One set containing varying proportions of sunflower oil methyl esters (SOME) with diesel and another set containing various proportions of nigerseed oil methyl esters (NOME) with diesel. Viscosity, specific gravity and calorific values were determined for these blends.

In the present work, the following percentages of biodiesel with diesel were prepared to study engine performance and emission characteristics. The blends are 5% (B5), 10% (B10), 15% (B15), 20% (B20) of biodiesel.

TABLE-3
COMPARISON OF PROPERTIES OF BIODIESEL WITH DIESEL

S.No.	Characteristics	Diesel	Biodiesel	
			SOME	NOME
1.	Fuel composition	C10–C12 hydrocarbons	C12-C26 fatty acid methyl esters	C12-C22 fatty acid methyl esters
2.	Density (kg/L)	0.8316	0.887	0.8966
3.	Viscosity (cp)	2.2249	7.49	7.6
4.	Flash point (°C)	75	174	188
5.	Fire point (°C)	88	190	215
6.	Cetane number	40–45	48–60	48–60
7.	Calorific value (kcal/kg)	10,300	15,553	12,282

TABLE-4
FUEL PROPERTIES OF DIFFERENT BLENDS OF BIODIESEL WITH DIESEL

S.No.	Characteristics	5%Biodiesel (B5)		10% Biodiesel (B10)		15%Biodiesel (B15)		20%Biodiesel (B20)	
		SOME	NOME	SOME	NOME	SOME	NOME	SOME	NOME
1.	Density (kg/L)	0.8342	0.8334	0.8369	0.8374	0.840	0.8384	0.8483	0.8477
2.	Viscosity (cp)	2.3712	2.1000	2.5190	2.5300	2.879	2.6200	3.1020	2.8300
3.	Calorific value (kcal/kg)	9,2660	10,399	13,643	10,498	14,322	10,597	14,807	10,697

Specifications of the diesel engine used for experimentation:

Engine model: 4-stroke single cylinder internal combustion engine
Rated speed: 1500 rpm
Bore: 102 mm
Stroke: 110 mm

The engine model specified above was a single cylinder vertical 4-stroke high speed engine. It was electrically loaded by means of generator coupled to it.

The engine was first made to run on ordinary diesel at the rated speed for around 10 min before taking any readings. Then the time for the consumption of 10 cc of fuel at zero load was recorded using a stopwatch and the corresponding reading was noted on the smoke meter. Gradually, the load was increased from 5 A to 25 A keeping the voltage constant at 230 V. The engine was allowed to run for a minimum of 5 min at each load before taking the corresponding readings for fuel consumption and per cent smoke.

The above procedure was repeated for each of the various blends of SOME (sunflower oil methyl ester) and NOME (nigerseed oil methyl ester) with diesel, starting from 5% (B5) in the ascending order up to 20% biodiesel substitution (B20). The fuel consumption, efficiency of the engine, exhaust smoke were calculated for the biodiesel blends. The performance of biodiesel blend was compared with that of pure diesel.

The characteristic curves for different blends were presented in the form of graphs reflecting various performance parameters.

RESULTS AND DISCUSSION

The nigerseed oil methyl esters and sunflower oil methyl esters were prepared by using methanol in transesterification reaction. The prepared methyl esters were

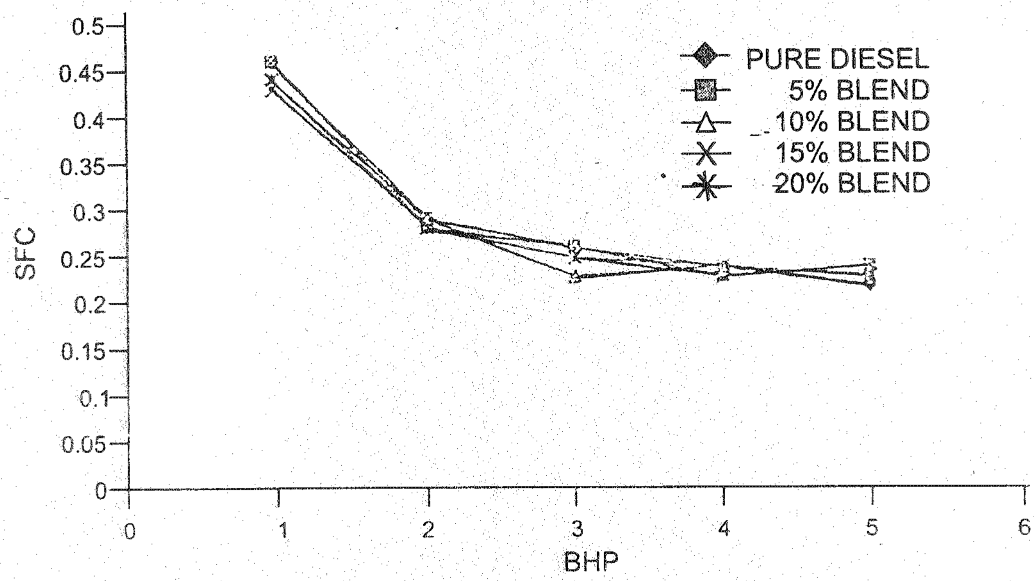

Fig. 1. (a) Comparison of biodiesel blends with pure diesel for specific fuel consumption (SOME)

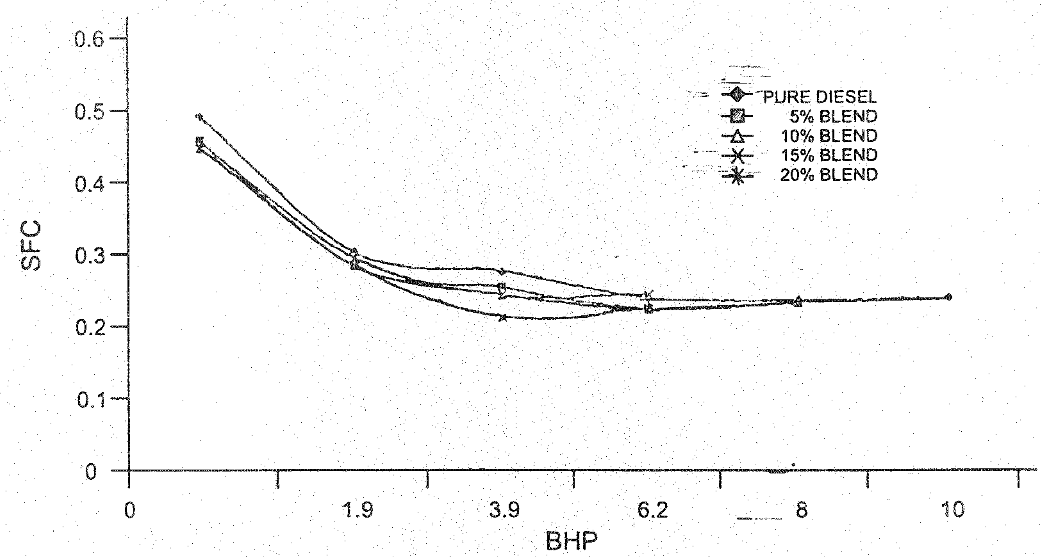

Fig. 1. (b) Comparison of biodiesel blends with pure diesel (BHP *vs.* SFC) for specific fuel consumption (NOME)

blended with diesel in various proportions and the blends prepared and studied are 5, 10, 15 and 20% of biodiesel. The properties such as density, specific gravity, viscosity, kinematic viscosity and calorific values were evaluated for the prepared esters and diesel oil (Table-4).

It is observed that up to 20% by weight of biodiesel can be safely blended with diesel to run an IC engine without any changes in the design of the existing engine, giving the same performance and showing less environmental pollution, which paves the way for augmenting to some extent the non-renewable fossil fuel (Figs. 1–3).

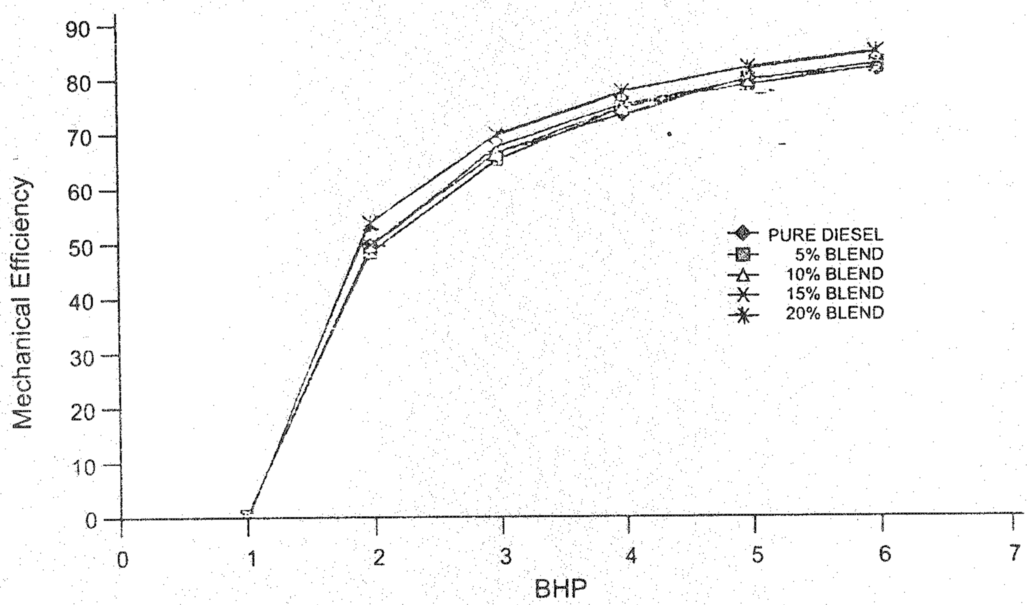

Fig. 2. (a) Comparison of biodiesel blends with pure diesel for mechanical efficiency (SOME)

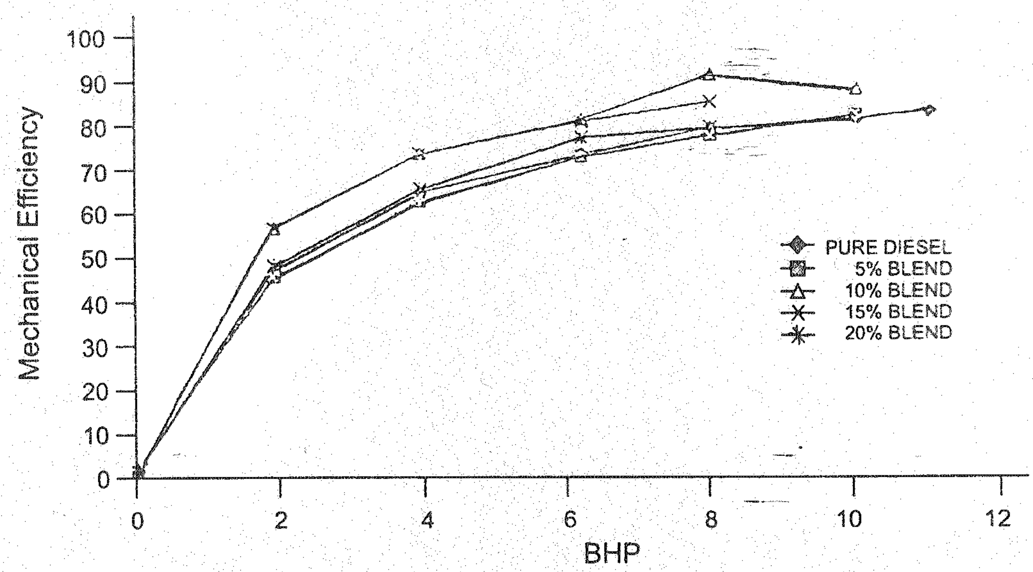

Fig. 2. (b) Comparison of biodiesel blends with pure diesel for mechanical efficiency (NOME)

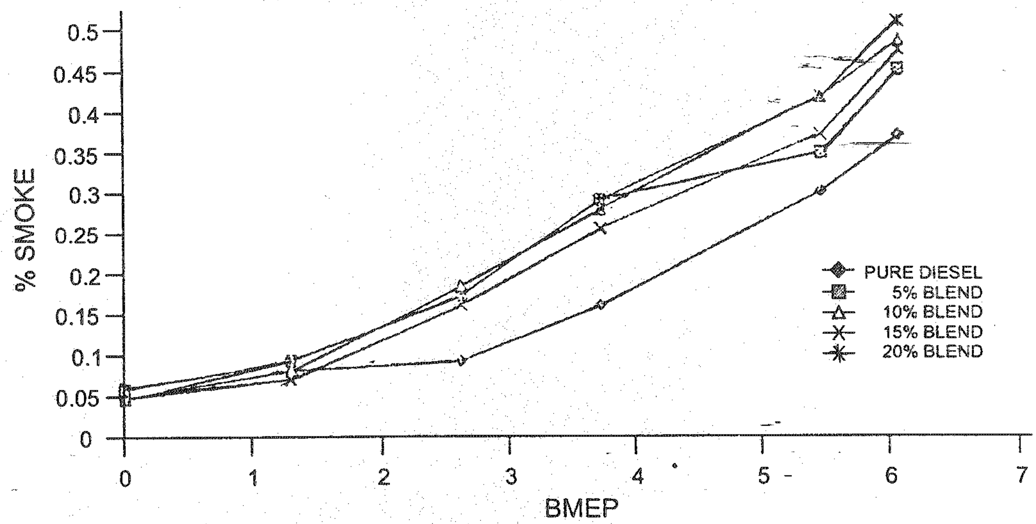

Fig. 3. (a) Comparison of biodiesel blends with pure diesel for smoke density (SOME)

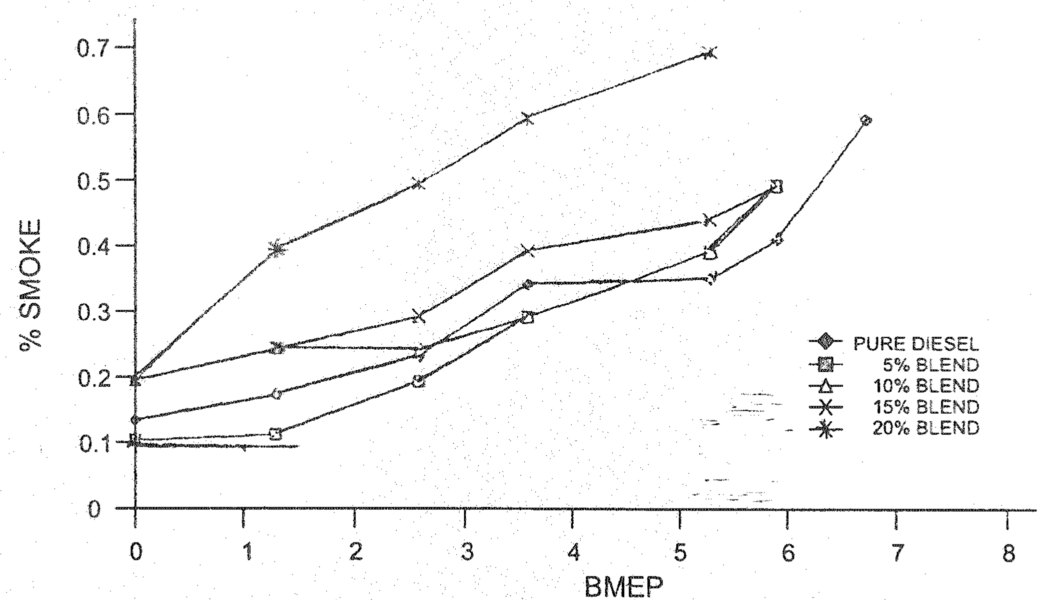

Fig. 3. (b) Comparison of biodiesel blends with pure diesel for smoke density (NOME)

Conclusions

The study suggests that transesterification was a convenient method for conversion of vegetable oils to biodiesel.

The two most important properties of vegetable oils that affect engine durability are viscosity and degree of unsaturation, which were brought to acceptable limits by transesterification. The yields of methyl esters were found to be around 94–96% by transesterification, which makes it one of the most effective and promising methods of biodiesel production. The biodiesel produced showed viscosity well within the range of diesel oil. Blends of biodiesel and diesel were found to be completely miscible and gave stable mixtures. Engine studies showed that there was substantial decrease in exhaust smoke for lower concentration of ester in blends. Biodiesel was found to have good lubricating properties and hence the chances of wear out can be substantially reduced. Flash and fire points of biodiesel are comparatively higher for esters; thus the risk of fire hazards gets reduced and handling and storage of biodiesel is safer. Using biodiesel blends enhanced the engine performance without significant increase in emission levels.

Of the various blends of biodiesel prepared from sunflower and nigerseed oil, which were used to study engine performance, it can be concluded that the diesel engine can run smoothly on 5–20% substitution with biodiesel with performance characteristics comparable with that of diesel. Thus, the optimum blends considering exhaust emission levels and engine performance were found to be 20% substitution with sunflower methyl ester and 15% substitution with nigerseed oil methyl ester.

The use of these ester blends can be effective in existing engines without any engine modifications and the system exhibited considerable reduction in emission levels. Use of these ester blends as a partial diesel substitute can go a long way in conservation measures, boosting farm economy and reducing uncertainty of availability. It diminishes the dependence on imported crude oil and increases energy security. Biodiesel helps to insulate countries for sudden interruptions or sudden price fluctuations in their energy supply.

It would not be wrong if we refer biodiesel as the "Green Gold" of the 21st century instead of the conventional way of referring fossil fuel as "Black Gold".

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(*Received*: 14 October 2005; *Accepted*: 2 May 2006) AJC-4826