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Improvement of engine emissions with conventional diesel fuel and diesel–biodiesel blends

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Abstract

In this report combustion and exhaust emissions with neat diesel fuel and diesel–biodiesel blends have been investigated. In the investigation, firstly biodiesel from non-edible neem oil has been made by esterification. Biodiesel fuel (BDF) is chemically known as mono-alkyl fatty acid ester. It is renewable in nature and is derived from plant oils including vegetable oils. BDF is non-toxic, biodegradable, recycled resource and essentially free from sulfur and carcinogenic benzene. In the second phase of this investigation, experiment has been conducted with neat diesel fuel and diesel–biodiesel blends in a four stroke naturally aspirated (NA) direct injection (DI) diesel engine. Compared with conventional diesel fuel, diesel–biodiesel blends showed lower carbon monoxide (CO), and smoke emissions but higher oxides of nitrogen (NO_x) emission. However, compared with the diesel fuel, NO_x emission with diesel–biodiesel blends was slightly reduced when EGR was applied.

Keywords: Neem oil; Esterification; Biodiesel; Diesel engine; Exhaust emissions and Exhaust Gas Recirculation (EGR)

1. Introduction

As world's petroleum supplies are becoming constrained, attention has been directed to find out alternative sources of fuels for engines. The non-renewable nature and limited resources of petroleum fuels have become a matter of great concern. After the 1973 oil embargo, it had been very important to study the alternative sources of fuel for diesel engine because of the concern over the availability and the price of petroleum based fuels. The present reservation of fuels used in internal combustion (IC) engines including diesel will deplete within 40 years if consumed at an increasing rate estimated to be of the order of 3% per annum. All these aspects have drawn the attention to conserve and stretch the oil reserves by way of alternative fuel research.

In Bangladesh, diesel is primarily used for transportation, agriculture and electric power generation. Despite, bangladesh's rapidly growing industries, it still has a very low per capita energy consumption of 245 kg of oil equivalent per year, as compared to 7200 kg for USA and 670 kg for china. As energy and economy are closely linked, it is realized that a growing economy will demand a much higher level of energy consumption.

Crops, which produce oil directly, are one of alternative sources of fuel. Of these oils, castor is the highest yielding oil producer. Commonly the processing of the castor fruit to extract the oil is done in plants, which use process residue to meet all plant fuel requirements. Because of these energy economics, the fossil fuel consumption to operate the entire castor oil production system is less than 10% of the energy contained in the castor oil produced.

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Nomenclature

CP^0	specific heat at constant pressure of each species (J/mol/K)	y_i	mol fraction of each species in combustion products
H_b	gas mol enthalpies after combustion (J/mol)		
$\Delta_f H_i^0(T)$	mol enthalpy of each species (J/mol)	*Greek symbols*	
H_u	gas mol enthalpies before combustion (J/mol)	α	mol number of carbon in unit mol of fuel
T	gas temperature (K)	β	mol number of hydrogen in unit mol of fuel
T_b	adiabatic flame temperature (K)	γ	mol number of oxygen in unit mol of fuel
T_0	initial atmospheric temperature (K)	ϕ	equivalence ratio

Castor and neem oils are renewable sources of energy and they are growing abundantly in india and bangladesh. castor and neem oils are non-toxic. Castor oil is regarded as one of the most valuable laxatives in medicine. Inspite of medical use, the esters of castor and neem oils have some important fuel properties that can be of help to use them as alternative fuels for diesel engine.

The problem with processing waste oils is that they usually contain large amount of free fatty acids that cannot be converted to biodiesel using an alkaline catalyst due to the formation of soaps. The soaps can prevent separation of the biodiesel from its co-product glycerin. An alternative way is to use acid catalysts, which have been claimed by some researchers (Aksoy et al., 1988) as more tolerant of free fatty acids. A process has also been developed (Canakci and Van Garpen, 2001a,b) to produce fuel quality biodiesel from yellow and brown grease using acid catalyst.

Methyl esters have been prepared (Mittlbach et al., 1992) from used frying oil and their fuel properties compared to Austrian standards valid for rapeseed oil methyl ester. The content of the free fatty acids of the oils was between 0.26% and 2.12%. After filtration at 40 °C to remove solid particles, the oil was transesterified using alkaline catalyst. It has been noted that all specification values could be met by the used vegetable oil esters except for the cold filter plugging point, which in most cases was over −8 °C.

10% and 20% blends (by volume) of methyl ester of used frying oil have been prepared (Isigigur-Tuna et al., 1990) with No. 2 diesel fuel and it was found that heating value and cetane number were a little lower than for No. 2 diesel fuel, and most of the fuel properties of the blends were within the range of those for pure No. 2 diesel fuel.

The esters of used frying oil have been investigated (Nye et al., 1983) to determine their effects on engine performance and emissions. THE esters of methanol, ethanol 1-propanol, 2-propanol, 2-butanol, and 2-ethoxymethanol were prepared using sulfuric acid and potassium hydroxide as acid and base catalysts, respectively. It was found that all of the acid-catalyzed fuels had low viscosities, but all of the base-catalyzed fuels had higher viscosities, except for the methanol-based fuel, which was the least viscous of all fuels. It was also noted that the viscosity results of the esters correlated with the percentage of ester yield indicating that some of the fuels probably contained substantial amounts of unreacted and partially reacted oil. In that study, the three fuels with the lowest viscosity, namely, methyl ester prepared with base catalyst, ethyl ester prepared with acid catalyst, butyl ester prepared with acid catalyst, were tested in half hour runs in a high-speed diesel engine. No problems were observed with the engine in regard to starting at 25 °C, smoothness of running, or smokiness of exhaust. The methyl and ethyl esters were also tested in a Perkins P6 low speed diesel engine and no problems were observed in that engine either.

The engine performance and emissions of ethyl esters produced from waste hydrogenated soybean oil have been compared (Peterson et al., 1995) with No. 2 diesel fuel. In this study, two types of engines were used. For the engine performance test, a direct injected, four-cylinder John Deere 4329t-turbocharged diesel engine was used. The emissions testing was conducted with a 1994 Dodge pickup equipped with a direct injected turbocharged and intercooled, 5.9L Cummins diesel engine. It was found that the biodiesel had a higher specific gravity and 1.9 times the viscosity of No. 2 diesel fuel at 40 °C. The heat of combustion of the biodiesel was noticed 12% lower than that for diesel fuel. It was observed that the smoke opacity and engine power were lower by 71% and 4.8%, respectively when the engine was operated with the biodiesel compared with No. 2 diesel fuel. But the peak engine torque was reduced by 6% and 3.2% at 1700 and 1300 rpm, respectively. However, there was no significant difference in the thermal efficiencies. Emissions tests showed a 54% decrease in HC, 46% decrease in CO, 14.7% decrease in NO_x, and 0.5% increase in CO_2 when biodiesel was used.

Waste cooking oils were converted (Reed et al., 1991) to their methyl and ethyl esters and tested pure biodiesel and 30% blend of biodiesel in diesel fuel in a diesel-powered bus using a chassis dynamometer. In this study no significant difference in power and performance was observed except for a visible reduction of smoke on