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Determination of effects of various alcohol additions into peanut methyl ester on performance and emission characteristics of a compression ignition engine

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HIGHLIGHTS

- Blending of 3 different alcohols with peanut biodiesel.
- Determining the fuel properties of blends.
- Constituting the performance and emission curves with respect to engine speed.
- Performing detailed cost analysis.

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ABSTRACT

In this experimental study, effects of various alcohol additions into peanut methyl ester (PME) with ratio of 20% (by vol.) are investigated. After determining fuel properties of ethanol–methyl ester (EME), methanol–methyl ester (MME) and buthanol–methyl ester (BME), their effects on engine performance and emissions are compared with PME and neat diesel fuel. It is observed that oxygen content of alcohols enhances combustion and increased engine power and torque values are achieved compared to PME. Also, improved combustion results in reduced carbon monoxide (CO) emissions and increased nitrogen oxides (NO_x). It is concluded that, average increments of 2.4%, 10% and 12.8% are obtained for MME, EME and BME, respectively compared to PME, in terms of engine power. Average increments of 1.2%, 3.4% and 6.1% are obtained for MME, EME and BME, respectively compared to PME, in terms of engine torque. Average reductions of 4.8%, 1.8% and 9.1% are achieved for MME, EME and BME, respectively compared to PME, in terms of CO emissions and average increments of 13.8%, 4.1% and 17.4% are achieved for MME, EME and BME, respectively compared to PME, in terms of NO_x emissions. On the other hand, average reductions of 26.36%, 20.85% and 18.91% are attained for MME, EME and BME, respectively compared to neat diesel fuel, in terms of engine power. Average reductions of 20.53%, 18.81% and 16.67% are acquired for MME, EME and BME, respectively compared to neat diesel fuel, in terms of engine torque. Average reductions of 12.17%, 9.37% and 16.14% are obtained for MME, EME and BME, respectively compared to neat diesel fuel, in terms of CO emissions and average increments of 18.49%, 8.26% and 22.19% are achieved for MME, EME and BME, respectively compared to neat diesel fuel, in terms of NO_x emissions.

1. Introduction

Depletion on petroleum-based fuels directed researchers to search new alternative fuels. In this respect, biodiesel and alcohols seem as good alternatives [1–5]. Beside their pure usage in internal combustion engines, usage of their blends with petroleum-based fuels is getting importance day by day.

High viscosity value that causes challenges in fuel pumping is one of the major problems of biodiesel fuel [6–11]. Therefore, alcohol can be used as additive to enhance viscosity. On the other hand, addition of alcohol additives tends to reduce particulate matter (PM), unburnt hydrocarbon (UHC) and CO significantly in the exhaust emission due to the additional oxygen in fuel [12–16].

Alcohol can be produced from renewable resources like biomass from locally grown crops and even waste products such as waste paper, grass and tree trimmings. Requirement of little hardware modifications make alcohol fuels attractive for transportation [17].

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There have been various studies about biodiesel production from different feedstocks and their effects on engine performance and emissions characteristics [18–25]. For decades, many researchers have studied on performance, combustion and emission characteristics of internal combustion engines fuelled with biodiesel with alcohol additives. Yilmaz compared performance and emission characteristics of the engine fueled with biodiesel–methanol–diesel (BMD) and biodiesel–ethanol–diesel (BED) with standard diesel fuel as the baseline. Higher brake specific fuel consumption (BSFC) values were obtained from biodiesel–alcohol–diesel blends. When alcohol concentrations in blends were increased, CO and HC emissions increased and NO emissions are reduced [26]. Yasin et al. evaluated that the performance and emissions of a small proportion of methanol (5% by volume) in a B20 blend and mineral diesel separately. The purpose of alcohol usage as a fuel additive is to improve the viscosity and density in the biodiesel blend [12]. Zhu et al. tested Euro V diesel fuel, biodiesel, and ethanol–biodiesel blends (BE) in a 4-cylinder direct-injection diesel engine to investigate the combustion, performance and emission characteristics of the engine under five engine loads at the maximum torque engine speed of 1800 rpm. Engine performance has improved slightly with 5% ethanol in biodiesel (BE5). The BE blends could lead to reduction of both NO_x and particulate emissions of the diesel engine [27]. Pidol et.al. investigated the effect of ethanol–biodiesel–diesel fuel blends on performances and emissions in conventional diesel and advanced low temperature combustions. They concluded that, in conventional diesel combustion, at lower loads and speeds, the weak ignitability of the ethanol blends resulted in unstable and incomplete combustion at lower loads [28]. Zhu et al. studied on effects of ethanol–biodiesel blends on particulate and unregulated emissions and they concluded that addition of ethanol into biodiesel yielded reduction of particle number concentration and particulate mass concentration [29]. Yilmaz et al. investigated on compression ignition engine emissions in biodiesel–ethanol–diesel blends as a function of ethanol concentration and they deduced that NO emissions were reduced for all ethanol concentrations in blends while high concentration of ethanol caused increased UHC emissions [30]. Campos–Fernández et al. investigated on comparison of performance of higher alcohols/diesel fuel blends in a diesel engine by using butanol and pentanol as alcohols and they concluded that butanol blends exhibited slightly better behavior than pentanol blends and neat diesel fuel in terms of brake specific fuel consumption [31]. Qi et al. carried out experimental investigations on performance and combustion characteristics of biodiesel–diesel–methanol blend fuelled engine. They used BD50 (50% biodiesel and 50% diesel in vol.) as baseline fuel and they concluded that power and torque outputs of BDM5 (methanol addition to BD50 by 5% in vol.) and BDM10 (methanol addition to BD50 by 10% in vol.) were slightly lower than those of BD50. BDM5 and BDM10 showed dramatic reduction of smoke emissions. CO emissions were slightly lower, and NO_x and HC emissions were almost similar to those of BD50 at speed characteristic of full engine load [32]. Hulwan and Joshi studied on performance, emission and combustion characteristic of a multicylinder direct injection (DI) diesel engine running on diesel–ethanol–biodiesel blends of high ethanol content and they deduced that significant reduction in smoke was observed for high ethanol content blends while CO emissions were drastically increased at low loads and decreased slightly at high loads for the blends [33]. Yilmaz and Sanchez carried out experiments on analysis of operating a diesel engine on biodiesel-ethanol and biodiesel-methanol blends and they concluded that biodiesel–alcohol blends, as compared to diesel, reduced NO emissions while increasing CO and HC emissions, at below 70% loads. It was also shown that biodiesel–ethanol blend was more effective than biodiesel–methanol for emission reduction and overall engine performance [34]. Li et al. studied on combustion and emission characteristics of a two-stroke diesel engine operating on alcohol and they proposed an approach to its ignition problem by combining internal exhaust gas recirculation (EGR) with injection of small diesel fuel. They concluded that engine could run on alcohol with almost zero level of smoke and low exhaust gas temperature, and that the engine operating on alcohol had lower NO_x emissions and 2–3% higher effective thermal efficiency than that operating on diesel fuel in moderate and high load zones [35]. Anand et al. carried out an experimental investigations on combustion, performance and emissions characteristics of neat karanji biodiesel and its methanol blend in a turbocharged, DI, multi-cylinder truck diesel engine fitted with mechanical distributor type fuel injection pump diesel engine under constant speed and varying load conditions without altering injection timings. The results showed that the UHC and CO emissions were slightly higher for the methanol blend compared to neat biodiesel at low load conditions whereas at higher load conditions UHC emissions were comparable for the two fuels and carbon monoxide emissions decreased significantly for the methanol blend. A significant reduction in nitric oxide and smoke emissions were observed with the biodiesel–methanol blend investigated [36]. Yasin et al. studied on fuel physical characteristics of biodiesel blend fuels with alcohol as additives and they concluded that a small concentration of alcohol, 5% and 10% by volume diluted in B20 blend fuel significantly reduced viscosity and density of the B20 blend fuel while flash point and cetane number were increased [37]. Yasin et al. experimented on characterization of a diesel engine operating with a small proportion of methanol as a fuel additive in biodiesel blend and they deduced that BSFC for B20 and B20 M5 (20% biodiesel and 5% methanol) increased, but the BSFC for mineral diesel decreased with the corresponding increase in engine speeds from 1000 rpm to 3500 rpm. They also observed significant reductions in CO and carbon dioxide (CO_2) but higher NO_x and NO when the diesel engine was operated with B20 and B20 M5. Doğan conducted an experimental study on the influence of n-butanol/diesel fuel blends utilization on a small diesel engine performance and emissions. He used a single cylinder, four stroke, unmodified, and naturally aspirated direct injection (DI) high speed diesel engine at constant engine speed (2600 rpm) and four different engine loads by using five-test fuels by using B5 (contains 5% n-butanol and 95% diesel fuel in volume basis), B10, B15, B20 and neat diesel fuel. He concluded that smoke opacity, nitrogen oxides, and carbon monoxide emissions reduced while hydrocarbon emissions increased with the increasing n-butanol content in the fuel blends. In addition, there was an increase in the brake specific fuel consumption and in the brake thermal efficiency with increasing n-butanol content in fuel blends [38]. Sayın et al. studied on the influence of operating parameters on the performance and emissions of a DI diesel engine using methanol-blended-diesel fuel in order to determine the injection pressure and timing on the performance and emission characteristics of a DI diesel engine using methanol (5%, 10% and 15%) blended-diesel fuel and they deduced that smoke opacity and CO emission decreased when injection timing was advanced [39]. Lujaji et al. investigated on fuel properties, engine performance, combustion and emissions of blends containing croton oil, butanol, and diesel on a CI engine and they concluded that addition of butanol in croton oil–diesel blends resulted in high cylinder pressure and improved heat release rate as compared to that of diesel fuel [40]. Lapuerta et al. investigated on emissions from a diesel–bioethanol blend in an automotive diesel engine. They deduced that a blend of 10% bioethanol in diesel fuel in volume, with no additives, proved that e-diesel blends could be an attractive alternative to partially substitute fossil fuels and to reduce particulate matter emissions, with no penalty in other gaseous emissions [41].