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Effects of physicochemical properties of biodiesel fuel blends with alcohol on diesel engine performance and exhaust emissions: A review

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ABSTRACT

In recent years, alternative fuel studies have been conducted thoroughly by researchers through their experimental work. Depletion of fossil fuel raised the attention of researchers to investigate renewable energy sources such as biodiesel and alcohol. There is a lack of literature review study on the viability of alcohol acting as additive in biodiesel-diesel fuel blends. Thus, this review paper studies on the effects of various alcohol additives in biodiesel-diesel fuel blends on combustion behaviour, performance and emission characteristics of diesel engines. The physicochemical properties of alcohol and biodiesel are rigorously discussed, in which they are the main factors in determining the quality of the blended fuel. The aim of this paper is to identify the potential of alcohol fuel as an additive in the blended biodiesel and diesel fuel in correspond to the type of alcohol, blending ratio and engine operation conditions. Wide range of results from previous research studies with different types of compression-ignition engine, different engine operation conditions and varieties of alcohol-biodiesel-diesel fuel blending ratios were collected in this literature review study. Combustion behaviour such as coefficient of variations (COV), in-cylinder pressure, ignition delay, heat release rate and combustion duration are presented. Low cetane number and high latent heat of vaporization of alcohol cause a longer ignition delay, produce higher rate of heat release and lower in-cylinder pressure when compared with that of diesel fuel. Low density and viscosity of alcohol improve the spray characteristics and enhance air-fuel mixing process. In terms of engine performance analysis, the presence of oxygen in alcohol fuel promotes a more complete combustion; hence, resulting in an increase of thermal efficiency. In turn, emissions of carbon monoxide (CO), hydrocarbon (HC) and particulate matter (PM) are decreasing.

1. Introduction

Increasing demands in the automotive industry have caused the petroleum sources to decrease on a daily basis. Thus, this problem has raised an interest towards researching alternative fuel. Alternative fuel must be compatible and has to maintain or improve the engine performance such as engine power and output torque to replace the well-known diesel fuel. In achieving a better environment, research findings must also focus on the harmful exhaust emission. Besides that, particles from the emission have dangerous effects on health. A number of studies have been made which prove that emissions from vehicles can cause cardiovascular and respiratory health problems [1–4]. Among the proposed alternative fuels for diesel engines are alcohol and biodiesel fuels which have gained much priority from scientists and researchers. Furthermore, previous researches have shown that alternative fuel from renewable sources can improve engine performance in terms of fuel consumption and can reduce carbon monoxide (CO), unburned hydrocarbon (HC) and particulate matter emissions from diesel engine [5–7].

Biodiesel has the potential in fulfilling the environment and economic concerns as it is a renewable and sustainable energy source [8,9]. Availability and sustainability of biodiesel are some of the most important factors in determining the biodiesel productions [10,11]. Production cost is another factor that needs to be justified as it mainly depends on the feedstock cost in which it represents 75–80% from the overall cost [12]. Fuel standards for the requirements of biodiesel either in the neat form or blend components have been standardized by ASTM D6751 in the United States or EN14214 in the European as shown in Table 1.1, before it is approved and can be commercialized worldwide [13]. Physicochemical properties of biodiesel have been

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Nomenclature

DICI	Direct injection compression ignition
BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
NO_x	Nitrogen oxide
CO	Carbon monoxide
HC	Hydrocarbon
PM	Particulate matter
EGT	Exhaust gas temperature
COV	Coefficient of variations
EGR	Exhaust gas recirculation
IMEP	Indicated mean effective pressure
BMEP	Brake mean effective pressure
CA BTDC	Crank angle before top dead centre
SOI	Start of injection
AV	Acid value
CP	Cloud point
CFPP	Cold filter plugging point
PP	Pour point
IP	Introduction period
IV	Iodine value
KV	Kinematic viscosity

Table 1.1
Biofuel standards from ASTM D6751 and EN 14214 [13].

	Unit	ASTM D6751	EN142 14
AV	**mg KOH/g**	0.50 max	0.50 max
Free glycerol	**mass%**	0.020 max	0.020 max
Total glycerol	**mass%**	0.240 max	0.250 max
Flash point	**°C**	93 min	101 min
CP	**°C**	Report	–[b]
CFPP	**°C**	–[b]	Variable[c]
PP	**°C**	–[b]	–[b]
IP	**110 °C, h**	3 min	6 min
IV	**g I_2/100 g**	–[b]	120 max
KV	**40 °C, mm^2/s**	1.9–6.0	3.5–5.0
Moisture	**ppm**	–	500 max

studied in which they have advantages and disadvantages when compared to pure diesel fuel [14–17]. Biodiesel has a greater cetane number than diesel fuel, less sulphur contents, has no aromatics and consists of 10–11% oxygen by weight [18–20]. In determining the fuel consumption, fuel energy content is an important property that indicates the quality of blended biodiesel-diesel fuel at high blending ratio, as fuel energy content can affect the engine power output [21].

In order to improve the properties of biodiesel and solve the problems that occurred due to cold flow, blending biodiesel with diesel fuel is one of the most common methods [22]. Different feedstock of biodiesel can be used as a fuel blend and also as a fuel for diesel engine. At low blending ratio (20%), it has been approved as a fuel for the existing diesel fuel and has been classified under the standard of ASTM D7467. However, at high blending ratios, the fuel properties have become worsen for combustion process and emission of diesel engine. The measurement and evaluation of blended fuel property is an important indicator; thus, it will be easier to analyse the engine performance results by increasing biodiesel ratio in the blended fuel when the key properties are known.

Alcohol can be easily blended alone with fossil fuel or mixed with other types of alternative fuel to improve engine performance and reduce engine emission [23]. Diesel fuels which have been blended with alcohol will produce diesohol/e-diesel as suggested by ref. [24]. Previous investigations of alcohol such as methanol and ethanol have shown the results of reduced NO_x emissions and the particulate matter [25,26]. However, there is some drawback in using alcohol as fuels in diesel engines, such as its miscibility, decreased lower heating value (LHV), low cetane number, poor lubricating properties and stability problems when blended with diesel fuels [27,28]. Higher alcohols such as butanol and pentanol have been used as blending component in diesel fuels due to its higher miscibility [28,29]. Despite the advantages of the oxygen contents of alcohol, the fuel properties such as viscosity, cetane number and lubricity of higher alcohol-diesel blends still need to be improved [30].

In order to overcome the disadvantages of biodiesel and alcohol, blending of biodiesel with low and high alcohols can improve the properties of diesel fuel [31]. For example, the lower viscosity and higher volatility in alcohols would be improved with the addition of biodiesel. Furthermore, the increased oxygen content of the blended fuel can improve the combustion process. Extensive research had been carried out to investigate various types of alcohol such as methanol-biodiesel blends, ethanol-biodiesel blends, isopropanol-biodiesel blends, butanol-biodiesel blends and pentanol-biodiesel blends. From those studies, a variety of results was recorded with respect to combustion behaviour, engine performance and exhaust emissions.

Thus, this review paper aims to investigate the improvement of varieties of alcohol-biodiesel-diesel fuel blends on combustion, performance and emission characteristics of a diesel engine.in comparison with those of pure diesel, biodiesel and alcohol-diesel blended fuels. Literature study in this paper was collected within the recent years of 2000–2017 to strengthen the information and findings for the specified parameters. In the current literature review, three sections are provided; biodiesel feedstocks, alcohol feedstocks and alcohol-biodiesel-diesel feedstock. These three sections generally provide the literatures in their respective properties, type of feedstocks, and their impacts on combustion, performance and emission characteristics of a CI engine. A brief detail on the results of previous studies is also provided for the alcohol-biodiesel-diesel fuel blends in terms of table and comprehensive discussion. Coefficient of variation, combustion pressure, ignition delay, heat release rate and combustion duration are among those parameters of combustion analysis highlighted in this study. Engine power, engine torque, brake specific fuel consumption

Table 2.1
Types of biodiesel [34,35].

Type of biodiesel	Example	Explanation
Vegetable oil	Edible vegetable oil: *Rapeseed, soybean, coconut, palm, sunflower, peanut, olive and sesame seed.*	Edible vegetable oil: Compete with food materials and sources to be used in diesel engine
	Non-edible vegetable oil: *Jatropha curcas, karanjaorpongamia, jojoba, cottonseed, algae and sea mango.*	Non-edible vegetable oil: Second generation feedstocks as it will be the substitution for edible sources.
Animal fats oil	Chicken fat, yellow grease and by-products from fish oil.	Layer of fats derived from animals. Made of triacylglycerols, diacylglycerols and monoacylglycerols.
Waste/used cooking oil	Oil and grease from households, restaurants and food processing factories.	Recycle waste products and prevent the wastage disposal problems.