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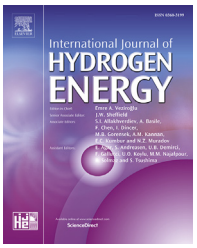

Hydrogen addition to tea seed oil biodiesel: Performance and emission characteristics

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ABSTRACT

Compression ignition engines are the dominant tools of the modern human life especially in the field of transportation. But, the increasing problematic issues such as decreasing reserves and environmental effects of diesel fuels which is the energy source of compression ignition engines forcing researchers to investigate alternative fuels for substitution or decreasing the dependency on fossil fuels. The mostly known alternative fuel is biodiesel fuel and many researchers are investigating the possible raw materials for biodiesel production. Also, hydrogen fuel is an alternative fuel which can be used in compression ignition engines for decreasing fuel consumption and hazardous exhaust emissions by enriching the fuel. In this study, influences of hydrogen enrichment to diesel and diesel tea seed oil biodiesel blends (B10 and B20) were investigated on an unmodified compression ignition engine experimentally. In consequence of the experiments, lower torque and higher brake specific fuel consumption data were measured when the engine was fuelled diesel biodiesel blends (B10 and B20) instead of diesel fuel. Also, diesel biodiesel blends increased CO_2 and NO_x emissions while decreasing the CO emissions. Hydrogen enrichment (5 l/m and 10 l/m) was improved the both torque and brake specific fuel consumption for all test fuels. Furthermore, hydrogen enrichment reduced CO and CO_2 emissions due to absence of carbon atoms in the chemical structure for all test fuels. Increasing flow rate of hydrogen fuel from 5 l/m to 10 l/m further improved performance measures and emitted harmful gases except NO_x. The most significant drawback of the hydrogen enrichment was the increased NO_x emissions.

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Introduction

The energy supply is the main challenge all around world and many problematic issues in the world are related with energy. The main part of the energy in our daily lives is coming from the fossil sources which are faced to a widely known fact depletion. With the decreased reserves, countries, researchers, policy makers have focused on alternative ways to overcome this significant problem. The most attractive solution for many researchers is renewable energy sources such as sunlight, wind, wave, geothermal etc. But, all these solution also must be applicable and sustainable for all regions. Apparently, these energy sources are very useful but not feasible for every region and for every time frame. Thus, researchers are investigating other alternatives which are renewable, sustainable, economical and feasible for most of the applications [1–5]. Recently, many researchers are

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attracted by hydrogen energy which is clean, renewable and sustainable in specific conditions [6–9]. The high energy density and absence of carbon is the main advantages of the hydrogen. But, problems such as cost of production, storage issues, hydrogen embrittlement are the main drawbacks of the hydrogen usage [10–16].

Transportation has always been a critical issue for human life in all ages of the human civilization. The continuity of the human vita is almost depends on the continuity of the transportation. The transportation sector is mostly dominated by vehicles operating with compression ignition (diesel) engines due to its ease of operation and higher fuel efficiency compared to its counterparts. The most part of the necessary energy for transportation is supplied by fossil based petroleum products such as gasoline, diesel fuel, kerosene, etc. To find an alternative to petroleum products is an obligation for our generation to provide the sustainability of the human civilization. Also, the environmental effects of the fossil fuels are threating the nature by polluting the air and the soil. Fossil emissions are causing many dangerous diseases and global warming. The climate is excessively changing in a very bad direction. While the some regions of the world are facing with threat of floods caused by excessive rains, some regions of the world are under the threat of the complete desertification caused by global warming.

Another solution offered by many researchers for these significant problems is biodiesel usage for diesel engines [15,16]. Biodiesel is a renewable energy source which is obtained from waste oils, animal fats and mostly from vegetable oil by transesterification reaction. The main advantage of the biodiesel over conventional fuels is being renewable and sustainable [17]. Also it is known that biodiesel combustion is better and fossil based diesel and thus emits lower carbon monoxide emission to the nature. But in contrary, biodiesel usage has some negative sides as the consistency issue of raw oil supply, higher fuel consumption caused by lower calorific value, improper viscosity values, bad cold working properties and high emission values of oxides of nitrogen (NO_x) due to higher combustion temperature of biodiesel. But still, biodiesel usage is the best possible alternative for diesel engines. Biodiesel is generally blended with diesel fuel and used in diesel engine without making any modifications on current engines [18–20].

Recently, many researchers have studied to enrich biodiesel with different fuels such as compressed natural gas, alcohol fumigation and hydrogen [21–29]. The absence of carbon in hydrogen fuel makes it a promising alternative for biodiesel enrichment. The preliminary studies show that enriching diesel and biodiesel fuel with hydrogen fuel improves the performance values of the engines. Thus, due to lower fuel consumption values, lower carbon monoxide (CO) and carbon dioxide (CO_2) emissions were emitted compared to pure diesel or diesel-biodiesel blends were obtained. Many researchers reported that, hydrogen addition to diesel and diesel-biodiesel blend fuels improved fuel consumption values. Also, many researchers reported that hydrogen addition significantly increases NO_x emissions.

Tea seed is a potential raw material for biodiesel production and it has quite similar properties to diesel fuel [30,31]. In this study, blends of diesel and tea seed biodiesel fuels were enriched with hydrogen addition at different rates of hydrogen flows. The hydrogen fuel was introduced into engine on intake valve. According to experiments performance and emission characteristics of the engine were evaluated.

Table 1 – Technical properties of the engine and hydraulic dynamometer.

Brand	Mitsubishi Center (Test Engine)
Model	4D34-2A
Configuration	Inline 4
Type	Direct injection diesel with glow plug
Displacement	3907 cc
Bore	104 mm
Power	89 kW@3200 rpm
Torque	295 Nm@1800 rpm
Air Cleaner	Paper element type
Weight	325 kg
Brand	Netfren (Hydraulic Dynamometer)
Torque Range	0-1700 Nm
Speed Range	0-7500 rpm
Body Diameter	250 mm
Torque arm length	250 mm
Torque	295 Nm @ 1800 rpm

Experimental procedure

In this study, performance and emission characteristics of a four stroke unmodified compression ignition engine (Table 1) were evaluated while operating with hydrogen enriched blends of diesel and biodiesel fuel which is obtained from transesterification of tea seed oil. A hydraulic dynamometer (Table 1) and an emission analyser (MRU Delta 1600V) were used in order to observe performance and emission characteristics of the test engine, respectively. The experimental studies were conducted in Laboratories of Automotive Engineering Department, Çukurova University.

The first step for biodiesel production was the extraction of the oil. The oil was obtained from tea seeds by utilizing

Table 2 – Test fuels and energy substitution ratio of H_2 addition.

Test Fuel	Diesel (by volume)	Biodiesel (by volume)	H_2 (litre/minute)	$E(H_2)$(%) (Maximum)
D (H0)	100%	–	–	–
D(H5)	100%	–	5	1015
D(H10)	100%	–	10	1929
B10 (H0)	90%	10%	–	–
B10 (H5)	90%	10%	5	0,932
B10 (H10)	90%	10%	10	1797
B20 (H0)	80%	20%	–	–
B20 (H5)	80%	20%	5	1048
B20 (H10)	80%	20%	10	1996

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