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Emission and engine performance analysis of a diesel engine using hydrogen enriched pomegranate seed oil biodiesel

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ABSTRACT

The aim of this study is to determine the availability of pomegranate seed oil biodiesel (POB) as an alternative fuel in diesel engines and evaluate engine performance and emission characteristics of pure hydrogen enriched POB using diesel engine. For this purpose, the intake manifold of the test engine was modified and hydrogen enriched intake air was supplied throughout the experiments. Physical properties of POB and its blend with diesel fuel were also determined. The results showed that measured physical properties of POB are comparable with diesel fuel. According to engine performance experiments, although POB utilization has slight undesirable effects on some engine performance parameters such as brake power output and specific fuel consumption, it can be used as alternative fuel in diesel engines, by this way CO emission can be improved. Finally, hydrogen enrichment experiments indicated that pure hydrogen addition causes a slight improvement in both engine performance and exhaust emissions.

Introduction

The rapid increase in world's population and industrialization have emerged extreme ascend on global energy demand and it is expected to rise by 57% until the year 2050 [1–3]. Since fossil fuels are the most common reserve until now, the reserves face the threat of finality and leading environmental degradation in all over the world [4]. Therefore, in recent decades, researchers have significantly focused on alternative fuels which are sustainable, environmentally friendly, and financially reasonable [5,6]. Diesel is extensively used in transportation, power generation and other industrial applications [7]. Biodiesel which is derived from animal fats or vegetable oils has gathered great public attention due to resembling fuel properties to conventional diesel fuel [8,9]. Biodiesel has also the advantages what researchers care; such as being renewable and environmentally friendly [10]. However, some disadvantages of biodiesel such as higher viscosity and higher nitrogen oxides (NO_x) exhaust emissions enforce it to be blended with conventional diesel fuel [11]. Another drawback of biodiesel production is a lack of available arable land for a large amount of production. Moreover, production from edible feedstocks may cause to increase food prices [12,13]. Plant waste has many advantages in this perspective; they are non-edible and they do not occupy any additional land.

A number of studies about biodiesel production from waste plant seed and effect on diesel engine were presented in the

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last few years. Fadhil et al. (2017) produced biodiesel from *Silybum marianum* L. seeds oil [2]. Rashid et al., 2013, investigated *Citrus reticulate* seed oil as biodiesel production. They found out that cetane number, kinematic viscosity, flash point, and density of the methyl ester comply both ASTM D6751 and EN 14214 standards [14]. A diesel engine was fueled with Pistacia Chinensis Bunge seed biodiesel blend by Ma et al. (2011) [15]. Engine experiments showed that carbon monoxide (CO), hydrocarbon (HC), and smoke emissions decreased whereas NO_x emissions increased with higher biodiesel ratio.

Punica granatum L., known as Pomegranate belongs to the family of Punicaceae. It is widely available in Iran, Pakistan, and India [16,17]. The seeds of Pomegranate are usually a waste for food industry [18]. Averagely, the seeds of pomegranate are about 37–143 g at 1000 g of fruit and on a dry weight basis, oil content is generally between 12% and 20% [19].

Recently, investigation on hydrogen enriched diesel engine has come into prominence due to its great potential for environmental benefits. Tsujimura and Suzuki (2017) have injected hydrogen at the intake port of a single cylinder diesel engine in order to observe the effect of different hydrogen fraction under a specific engine operating condition. They illustrated that usage of hydrogen gas instead of conventional diesel fuel caused significant reduction of CO_2 emission and cylinder head temperature dependency on hydrogen fraction over 50% [20]. At the study of Homammad Hosseini et al. (2017) measured 17%, 8%, 69%, and 9.5% lower CO, CO_2, unburned hydrocarbon, and soot emissions, respectively and 2% higher NO_x emissions with the addition of hydrogen as a fuel excess [21]. Parthasarathy et al. (2016) asserted that the increment of NO_x can be diminished with biodiesel and ethanol blends [22]. The effect of biodiesel and hydrogen gas on engine vibration, noise, and exhaust emissions were investigated by Uludamar et al. (2016). The study concluded that both biodiesel and hydrogen gas reduced engine vibration and exhaust emissions. However, the trend of engine noise was depended on biodiesel fuel [23].

In this study, biodiesel from Pomegranate seed oil was prepared in order to investigate its fuel properties. In experiments, intake air of the engine was also enriched with hydrogen gas when the experimental diesel engine was fueled with diesel and biodiesel. Engine characteristic of the diesel engine fueled with Pomegranate seed biodiesel-diesel blend was investigated with hydrogen gas enriched intake air.

Material and method

Biodiesel was produced from commercially used pomegranate seed oil via the transesterification method in Adana Science and Technology University, Laboratories of Mechanical Engineering Department. The steps of the method are reaction, separation, washing, drying, and filtering. In reaction step, oil was heated to 55 °C while 0,5% by mass sodium hydroxide as a catalyst was dissolved in 15% by mass methanol (reactant) in another beaker. The mixture was poured on preheated oil and stirred for 90 min at 55 °C. After the reaction period, separation step was carried out. In this step, the crude methyl ester was kept inside a funnel for 10 h in order to separate crude glycerin. The separated methyl ester was repeatedly washed with 20% percent by volume warm water until the washed water became clear in washing step. Then, the dry operation was applied for 1 h at 110 °C. Small impurities inside the methyl ester were removed in the last step.

The fuel blend was prepared by blending 20% Pomegranate seed oil biodiesel with 80% conventional diesel fuel (B20). Diesel biodiesel and their blend properties were analyzed in Çukurova University, Petroleum Research and Automotive Engineering Laboratories of Automotive Engineering Department.

Engine experiments were conducted on a four stroke, four-cylinder Mitsubishi Canter 4D31 diesel engine, with the aid of TT electric AMP 160-4B electrical dynamometer. Hydrogen gas with 5 l/min flow rate was injected in intake air of the engine. The specifications of the engine were given in Table 1. In experiments, the exhaust emissions were measured with MRU Delta 1600-V gas analyzer. CO, NO, and NO_2 were measured in electrochemical cells whereas CO_2 was measured with NDIR Multi-gas bench. The range and accuracy of CO, NO, and NO_2 are 0–4000 ppm and ±20 ppm, 0–1000 and ± 5 ppm, and 0–200 ppm and ±5 ppm, respectively. The range of CO_2 is 20% with ±0,5% accuracy.

Technical specifications of the test engine

During engine performance determination experiments, the engine was operated up to a constant temperature. When the temperature had reached a constant value, the data was collected. Before the introduction of a new fuel, the fuel line was cleaned up.

Property analysis

In this study, methyl ester produced from pomegranate seed oil and a mixture of pomegranate seed oil biodiesel (POB) and diesel fuel was used as an alternative fuel. Diesel fuel was also used as a reference in order to compare the fuel properties of POB. POB and diesel fuel are mixed in the volumetric ratio of 20% (B20), which is the most common ratio in the world. After preparing the mixtures, the fuel properties of diesel fuel, POB, and B20 were determined in Çukurova University Automotive Engineering Laboratories. The tests were repeated three times and the average of the three results was taken. The results of fuel properties measurement test are shown in Table 2.

Table 1 – Technical specifications of the test engine.

Brand	Mitsubishi canter
Model	4D31
Configuration	In line 4
Type	Direct injection diesel with glow plug
Displacement	3298 cc
Bore	100
Stroke	105
Power	91 HP @ 3500 rpm
Torque	223 Nm @ 2200 rpm
Oil cooler	Water cooled

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