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Effects of fuels produced from fish and cooking oils on performance and emissions of a diesel engine

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ABSTRACT

In this study, two fuels called as FOME (Fish Oil Methyl Ester) and COME (Cooking Oil Methyl Ester) were produced from waste fish and cooking oils using the transesterification method. Commercial D2 (Diesel fuel) and two fuel samples obtained by blending the FOME and COME with the D2 with a ratio of 25% on volume basis were used as fuels in a Diesel test engine. An experimental study was performed for investigating the performance and exhaust emissions of the Diesel engine using the fuels. According to the test results, it was observed that the fish oil based fuel indicated better performance and exhaust emission parameters than those of cooking oil. Results clearly showed that the engine power and torque values were lower than those of the Diesel fuel with values of 3.05% and 1.25% for FB25, and 4.07% and 2.2% for CB25, respectively. Also, brake specific fuel consumption for the produced fuels increased up to 5.69% compared to Diesel fuel. However, HC and CO emission reductions compared to the Diesel fuel were found to be around 16.24% and 19.81%, respectively. But, the amount of increase in NO_x emissions for the same biodiesel fuels reached up to 17.2%.

1. Introduction

Because of the depletion of fossil fuel reserves and the increase in their negative effects on the environment, studies about renewable and clean energy sources have gained importance. Biodiesel is a type of renewable and also environment-friendly alternative fuel that can be used in Diesel engines. It is used as an alternative fuel to diesel fuel in internal combustion engines, and is produced from vegetable oil and animal waste. High viscosities of waste oils that are used in the production of biodiesel fuels cause pumping problems and spraying difficulties, and also incomplete combustion when air mixture is not fully achieved. The best way to resolve such problems is to convert oils produced from vegetables and animal waste into biodiesel so that they can be used as fuels in internal combustion engines.

Many hazardous wastes have occurred with the development of the industry. They have many negative effects on the environment and human health. In order to reduce their negative effects, recycling or re-utilizing of the wastes is a good solution. There are many types of waste oils which have harmful effects on the environment. The waste oils can be classified into three groups: vegetable waste cooking oils, waste animal fats and oils in the form of industrial waste. In addition, vegetable and animal oils/fats are divided into two parts as edible and inedible oils. Generally, biodiesels are produced from edible oils which have low free fatty acids. This increases cost of biodiesel that is produced from oils used as food purposes. The use of non-edible oils for biodiesel production can significantly reduce the cost of biodiesel. Therefore, the most appropriate feed stocks for biodiesel production are waste oils [1–3].

There is large amount of waste oils discharged to the environment as a result of their use in Turkey. About 400,000 tons of waste cooking oil in every year is wasted due to high amount of oil consumption in Turkey [4]. Around 100 tons of animal and vegetable oils are consumed per day only in Istanbul which is the largest city of Turkey. Animal fat discharged to the environment is not estimated. About 10,000 tons of fish oil is produced from fish meal and oil factories at Black Sea region of Turkey. Because of high calorie of animal and vegetable oils, they were being used for producing of animal food before. However, now their usage in the animal food is prohibited due to harmful effects of many compounds on animal health. Production of biodiesel fuel from animal and vegetable oils has increased the importance of waste oils. In recent years, several studies about the production of biodiesel fuel from waste oils and

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reutilization of them have been performed on different types of waste oils [5–11]. Phan and Phan [6] carried out transesterification of waste cooking oils with methanol and KOH as catalyst. Felizardo et al. [10] carried out transesterification of WFO (waste frying oil) with different concentration of catalyst. They found that a catalyst/WFO ratio of 0.6% gives the highest yield of methyl esters. In another study [11], it is presented that optimum catalyst amount is approximately 0.5–0.6 g catalyst/100 g of plant oil triglyceride. In order to evaluate waste engine oils, Arpa et al. [12] produced diesel-like fuel from waste engine oil for an internal combustion engine, and they investigated effects of the fuel on engine performance and exhaust emissions. According to test results, they concluded that the properties of diesel-like fuels were similar to petroleum-based diesel fuels and these can be used as cost-efficient fuels in internal combustion engines. Lin and Li [13] produced fish oil using mixed species of marine fish wastes and then converted the oil into biodiesel through the transesterification method. In addition, by utilizing the same method for waste cooking oil, they produced biodiesel and analyzed fuel properties. To determine the emission values of the fuels, they used them as fuels in an internal combustion engine, and investigated the effects on exhaust emissions of the fuels. In the same study, the emission characteristics of waste cooking oil and marine fish biodiesel, such as CO (carbon monoxide), CO_2 (carbon dioxide), unburned HC (hydrocarbon), NO_x (nitrogen oxides) and smoke, and exhaust gas temperature were measured and compared with commercial diesel fuel. Tashtoush et al. [14] investigated the interaction between temperature and time of conversion of waste animal fat into biodiesel. They determined that the most suitable temperature is 50 °C, and the best duration is two hours for conversion of waste animal fat into biodiesel. In another study, Gürü et al. [15] used biodiesel obtained from chicken fat in direct injection diesel engine as a fuel and analyzed the effect of that fuel on exhaust emissions and engine performance.

Biodiesel can be used as an alternative fuel to D2 (Diesel fuel) in Diesel engines in the form of pure and mixture with Diesel fuel in definite ratios. Due to properties of the biodiesel fuel, it can be mixed easily with all proportions of the D2 fuel. European Union countries have decided that higher and higher amounts of biodiesels should be added to fossil fuels ever since 2005. According to the decision, it is aimed at reaching the level of 2% in 2005, 5.75% in 2010 and 20% in 2020. Math [16] converted waste cooking oils into biodiesel and used them as fuels in a single-cylinder diesel engine and tested them both in pure form and in mixture form with specific proportions of diesel fuel. It was concluded that the diesel engine could work without any problems. As a result, a blend of diesel fuel and biodiesel with 20% did not cause any disruption on engine performance, and it could be directly used as a fuel in a diesel engine without any alterations. Utlu and Kocak [17] used waste cooking oil to obtain cooking oil methyl ester. After determining the physical and chemical properties of the cooking oil methyl ester, they tested it in turbocharged four-cylinder direct-injection diesel engine. The obtained test results of diesel fuel compared with exhaust emissions (CO, CO_2, NO_x and smoke) were lower than that of diesel fuel. Lapuerta et al. [18] obtained methyl and ethyl esters from two different alcohols (methyl and ethyl alcohols) of waste cooking oil. Each of methyl and ethyl esters were blended by 30% and 70% with D2 fuel, and then the fuel mixture was formed. Later, methyl and ethyl esters both in pure form and blend fuels were tested by using a four-cylinder, four strokes, turbocharged, intercooled direct-injection diesel engine. They compared the results with those of D2 test results, and examined the effects of different types of alcohol on exhaust emissions. Ilkilic [19] obtained a fuel by blending methyl ester produced from vegetable oil and D2 fuel by volume of 25%. He examined the effect of the blended fuel on exhaust emission of a diesel engine. Wayt et al. [20] obtained biodiesel from pig oil, animal tallow, chicken oil and soybean oil by using base-catalyzed transesterification method. They added this biodiesel to diesel fuel in ratio of 20%, and tested the blended fuel in one cylinder diesel engine. According to the test results, they obtained that animal oil based B20 (blend fuel) brings about less NO_x emission than soybean oil based B20 (blend fuel). FOME (Fish oil methyl ester) and its blends have been tested in a diesel engine by Bhaskar et al. [21]. They indicated that blend fuel with 20%vol. of FOME gives almost the same brake thermal efficiency with lower unburned hydrocarbons, carbon monoxide and soot emissions, but higher NO_x emissions compared to diesel fuel. An experimental study [22] was performed by using blend fuels with different ratios in a diesel engine. They show that maximum power and maximum thermal efficiency occur at blend of 17.5% vol. Godiganor et al. [23] obtained blend fuels (B10, B20, B40, B60, B80) by adding fish oil based biodiesel to D2 fuel by ratio of range from 10% to 80%. After testing these fuels, they acquired minimum specific fuel consumption and maximum brake thermal efficiency for B20 fuel. As a result of many studies, fish oil converted into biodiesel fuel and used as a fuel in internal combustion engines have revealed that exhaust emissions of FOME were lower than diesel fuel. Also, it was concluded that it could be used as an alternative diesel fuel by re-utilizing different types of surplus fish and thus reducing negative effects of waste fish on the environment [24–28].

In this study, two types of biodiesel fuels which were produced from waste fish and cooking oil in order to reuse the waste oils and to eliminate harmful effects of the waste oils on the environment. Some characteristics of the biodiesel fuels and D2 were tested. The fuels were used in a diesel test engine to examine their effects on engine performance and emission parameters. The performance parameters like brake power, engine torque, brake specific fuel consumption, brake mean effective pressure, and brake thermal efficiency were evaluated based on the experimental data collected from the test engine. The emission parameters such as CO, CO_2, HC, NO_x, SO_2 and smoke opacity were measured during the performance tests. The results obtained from the tests were discussed and compared with those of diesel fuel.

2. Materials and method

2.1. Potential of waste oil in Turkey

Considering the cost of bio-fuels, the most suitable raw materials for producing low-cost biofuels are waste oils. In Turkey, waste oils can be classified as waste cooking oil from vegetable oils, waste industrial and animal oils. In order to obtain biodiesel fuel, two types of waste oils were used in the present study, which are waste oil from anchovy fish and cooking oil from cotton. Potentials and use of the waste oils in the World are summarized in the following subsections.

2.1.1. Waste fish oil

For centuries, fish and by-products have been consumed as food by humans, but also used in animal nutrition. Despite the fact that 75 million tons of fish is captured all over the world annually, people consume only 1% of this amount. The captured fish amount used for the production of fish meal and oil is about one-third of it. Since early 19th century, surplus fish after drying and grinding has been used in animal nutrition. Fish meal and oil industry has developed in the North of Europe and North America. Several techniques have been used to obtain fish meal and oil products by processing plants. Fish oil has been used especially in aquaculture, poultry and pig farming, and industry, and a small amount of fish