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Effect of biodiesel from various feedstocks on combustion characteristics, engine durability and materials compatibility: A review

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ABSTRACT

The global energy consumption is expected to grow in a faster rate than the population growth. By 2030, an increase of 53% of global energy consumption and 39% of greenhouse gases emissions from fossil fuels is anticipated. Therefore, it becomes a global agenda to develop clean alternative fuels which are domestically available, environmentally acceptable and technically feasible. As an alternative fuel, biodiesel seems as one of the best choices among other sources due to its environment friendly behavior and similar functional properties with diesel. The main objective of this paper is to discuss the impact biodiesel from different edible, non-edible and waste cooking oils feedstocks on combustion characteristics, engine durability and materials compatibility with biodiesel. Moreover, this paper reviews some other important related aspects to biodiesel such as biodiesel development, biodiesel feedstocks, biodiesel standards and advantages and challenges of biodiesel.

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1. Introduction

It is well known that in modern economics, energy has the main role in the advancement of all sectors including agricultural, transportation, telecommunication and industrial sectors. As a result, worldwide energy consumption is expected to grow in a faster rate than the population growth [1]. According to the International Energy Agency (IEA), an anticipated increase of 53% of global energy consumption is foreseen by 2030. Energy consumption mostly comes from fossil fuels which account for 87% among other energy sources in which crude oil consisting of 33.06%, coal 30.34% and natural gas 23.67%, respectively. This is primarily due to their adaptability, high combustion efficiency, availability, reliability as well as the handling facilities [2]. The share of nuclear energy, hydropower and renewable energy are very small with only 4.88%, 6.44% and 1.58 of total energy usages, respectively. The world primary fuel consumption has grown from 6630 million tons of oil equivalent (Mtoe) in 1980 to almost double 12,274.6 Mtoe in 2011 as shown in Table 1 [3].

Emissions which are produced from burning petroleum derived fuels have a serious effect on both the environment and human health [4–6]. It is predicted that the greenhouse gases (GHG) emissions from fossil fuels will increase by 39% in 2030 if no enormous effort is done to alleviate it. Numerous factors such as worldwide environmental concerns, price hiking of the petroleum products as well as the expected depletion of fossil diesel fuel have encouraged to look over the clean combustion of diesel engines using alternative fuel sources [7–10].

Therefore, it becomes a global agenda to develop clean alternative fuels which are domestically available, environmentally acceptable and technically feasible. According to the Energy Policy Act of 1992 (EPACT, US), natural gas, biodiesel, ethanol, electricity and methanol are the main prospective alternative fuels that can reduce global warming, fossil fuels consumption and exhaust emissions [4,11]. As an alternative fuel, biodiesel is one of the best choices among others due to its environment friendly behavior and similar functional properties with diesel fuel. Using biodiesel in internal combustion engines can play a great role in reducing fossil fuel demand, environmental impact and the adverse effect on human health [12–16].

Table 1
Global primary energy consumptions in 1980, 2010 and 2011 [2].

Source	1980		2010		2011	
	Mtoe	Share (%)	Mtoe	Share (%)	Mtoe	Share (%)
Oil	2979.8	44.9	4031.9	33.66	4059.1	33.06
Natural gas	1296.8	27.3	2843.1	23.73	2905.6	23.67
Coal	1807.9	19.6	3532.0	29.48	3724.3	30.34
Nuclear	161.0	2.4	626.3	5.22	599.3	4.88
Hydropower	384.3	5.8	778.9	6.50	791.5	6.44
Renewable	–	–	165.5	1.38	194.8	1.58
Total	**6629.8**	**100**	**11,977.8**	**100**	**12,274.6**	**100**

However, using straight vegetable oils in engine may cause various engine problems such as injectors coking, carbon deposits on piston and head of engine and excessive engine wear [17]. For this reason it has been recommended by many researchers to transesterify vegetable oils to reduce the high viscosity of the oil. This transesterified vegetable oil is known as biodiesel or fatty acid methyl esters (FAME). Biodiesel is renewable and can be produced from edible and non-edible oil, recycled waste oils and animal fats by transesterification process [18–23].

1.1. Objective of this paper

Although there is a large number of literatures and researches on engine performances, combustion and emissions characteristics using biodiesel, especially in the last decades, only fewer people have analyzed and reviewed them [24]. This paper presents the potential of biodiesel from different sources and its impact on combustion characteristics including details of engine and operating condition. Moreover, engine durability and materials compatibility with biodiesel have also been covered in this paper. A large number of literatures from highly rated journals in scientific indexes are reviewed including most recent publications.

2. Background of biodiesel development

Biodiesel which is known as fatty acid methyl ester is produced from vegetable oils or animal fats using transesterification process in the presence or absence of catalyst. Biodiesel is non-explosive, biodegradable, non-flammable, renewable, and non-toxic as well as environment friendly [19,23,25]. This fuel has almost similar properties (such as cetane number, energy content, and viscosity and phase changes) with diesel fuel [26]. The major advantages of biodiesel are it can be blended with diesel fuel at any proportion and can be used in a diesel engine without any modification [27]. Moreover, it does not contain any harmful substances and produce less harmful emission to the environment.

In fact, Rudolph diesel has used vegetable oil (peanut oil) as a fuel in a diesel engine in August 10, 1893 [17]. Nonetheless, the conversion of vegetable oil into methyl ester employing the transesterification process was firstly conducted by E. Duffy and J. Patrick in 1853. In 1937, a patent “Procedure for the transformation of vegetable oils for their uses as fuels” from a Belgian scientist, named G. Chavanne was allowed and the concept of biodiesel was proposed for the first time [28]. In 1977, Expedito Parente, a Brazilian scientist, had applied for the first patent of “industrial process for biodiesel”. In the meantime, in South Africa and in 1979, research on biodiesel from sunflower oil was started. The engine-tested biodiesel was completed and it was published globally in 1983. The first pilot plant for biodiesel production was