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Production, characterization and performance of biodiesel as an alternative fuel in diesel engines – A review

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ABSTRACT

Due to the finite stock of fossil fuels and its negative impact on the environment, many countries across the world are now leaning toward renewable sources energies like solar energy, wind energy, biofuel, hydropower, geothermal and ocean energy to ensure energy for the countries development security. Biodiesel is one kind of biofuel that is renewable, biodegradable and has similar properties of fossil diesel fuel. The aim of this paper is to provide the substantial information on biodiesel to the researchers, engineers and policy makers. To achieve the goal, this paper summarizes the information on biofuel development, feedstocks around the world, oil extraction technic, biodiesel production processes. Furthermore, this paper will also discuss the advantages of biodiesel compared to fossil fuel. Finally, the combustion behavior of biodiesel in an internal combustion engine is discussed and it will help the researchers and policy maker and manufacturer. To determine the future and goal of automotive technology the study found that, feedstock selection for biodiesel production is very important as it associates 75% production cost. Moreover, the test of fuel properties is very important before using in the engine which depends on the type of feedstocks, origin country, and production process. Most of the researchers reported that the use of biodiesel in diesel engine reduces engine power slightly but reduces the harmful emission significantly. Finally, the study concludes that biodiesel has the potential to be used as a diesel fuel substitute in diesel engines to solve the energy and environment crisis.

1. Introduction

Transportation system plays an important role to develop the economy of any country in the world. Nowadays the key issue for worldwide transportation sector is the energy supply, which is being fulfilled by fossil fuels such as gasoline and diesel fuel. Globally, an average consumption of energy in the transport sector is increased by 1.1% per year due to the development of motorization industry. It has been reported that only the transportation sector have 63% share in the step up of total global liquid fuel consumption from the year of 2010–2040 [1]. Also, the significant growth of worldwide motorization industry has resulted in the increase of harmful pollutant emissions to the earth. It is very important to mention that, there are about 22% of global GHG (greenhouse gas) emission comes only from the transportation sector. Not only the International Energy Agency (IEA) predicted the emissions of GHG (carbon dioxide) from transport sector will be increased by 92% between 1990 and 2020 and it is also estimated that 8.6 billion metric tons carbon dioxide (CO_2) will be released to the atmosphere from 2020 to 2035 [2]. Vehicular emissions such as particulate matter (PM), hydrocarbon (HC), carbon dioxides (CO_2), carbon monoxides (CO) and nitrogen oxides (NOx) are hugely responsible for the air quality deterioration [3]. Fig. 1 shows the predictive share of transportation sector global energy consumption and CO_2 emission [4].

In Malaysia, the consumption of both petrol and diesel has been increasing rapidly with growing motorization and increasing dependence on private modes. At present, transportation sector consumes about 36% of the total national energy. Transportation sector consumes the largest portion of energy in Malaysia, and it's increasing every year. Energy consumption by transportation sector was increased from 1928 ktoe in 1978 to 17,180 ktoe in 2012. Fig. 2 shows the energy consumption by sectors in Malaysia [5]. Transport sector of Malaysia produced 42.4 million metric tons of CO_2 that shares 22.9% of total CO_2 emission in Malaysia. An increased number of registered motor vehicles is expected in years to come, which will certainly further increase the emission. It can be seen that CO_2 emission had increased from about 15 million metric tons in the early nineties to 42.43 million metric tons in 2012. As per calculation, transport sector needs to

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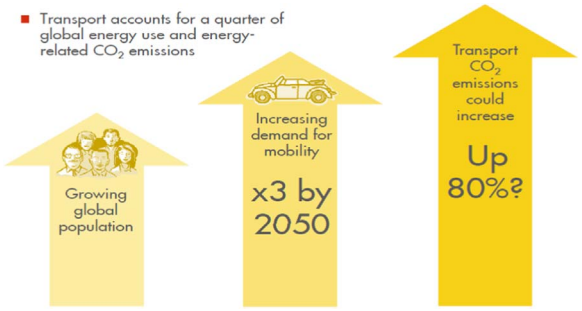

Fig. 1. Prediction on the share of transportation sector on global energy and CO_2 emissions [4].

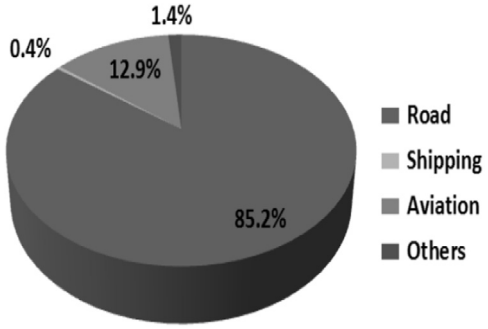

Fig. 3. Shares of different transport modes to total CO_2 emissions from transportation sector in Malaysia [6].

reduce CO_2 by 9.17 million metric tons to reduce 40% emission by the year 2020. Shares of different transport modes to total CO_2 emissions from the transportation sector are shown in Fig. 3 [6]. The road transportation has the major share (85.2%) of total GHG emission from transportation followed by the aviation, shipping, and other small sectors. Therefore, the major reduction of CO_2 emission should be achieved in road transportation.

Recently, worldwide researchers are trying to find out cleaner energy source for transportation sector that will come from the renewable energy source and will meet the energy and environment crisis [7]. Among the renewable energy sources, the biodiesel is considered as the most feasible cleaner fuel worldwide [8]. Fig. 4 shows the sectors in which biodiesel can be used as a diesel fuel replacement [9]. It is seen that biodiesel can be used as a substitute for diesel fuel in all the sectors including light vehicles. Heavy vehicles, equipment machinery, marine sectors, and remote generation. Thus the main aim of this paper is to study the potential of biodiesel as an alternative fuel in the transport sector.

2. Development of biodiesel

Vegetable oil (peanut oil) has been used as a fuel in a diesel engine by Rudolph Diesel on August 10, 1893 [10]. In 1853, a group of researchers first converted the vegetable oil into methyl ester through transesterification process. The concept of biodiesel was proposed for the first time in 1937, and a patent "Procedure for the transformation of vegetable oils for their uses as fuels" from a Belgian scientist G. Chavanne was granted. A Brazilian scientist Expedito Parente applied for the first patent for "industrial process for biodiesel" in 1977. In South Africa, research on biodiesel from sunflower oil was started in the year of 1979 [8]. An Austrian company established the first biodiesel pilot plant and industrial scales plant, Gaskoks in 1987 and 1989 respectively [11,12]. In 1991, the first biodiesel standard was issued. After that in 1997, A German standard (DIN 51606) was released. The first ASTM D6751 was published in 2002. In October of the following year, a new biodiesel standard DIN EN14214 was published in Europe. Later in September of the next year the first US state named Minnesota sold the diesel fuel that contained 2% biodiesel and then in 2008 October ASTM published the first biodiesel blend specification standard. The present version of the European standard EN 14214 was published in November 2008.

3. Potential sources of biodiesel

Oil crops are the main pillar for biodiesel production. It is very important to choose the suitable feedstock for biodiesel production as feedstock alone costs 75% of biodiesel production cost [11]. At present up to 350 oil-bearing crops have been identified worldwide for biodiesel production which is categorized as edible oil, non-edible oil [13]. The most common edible oil sources are: peanut oil, soybean oil, sunflower oil, safflower, corn oil, rice bran oil, palm oil, coconut oil, used fried oil, olive oil, rapeseed oil, castor oil, milkweed seed oil and linseed oil, wheat and common non-edible oil sources are: *Jatropha curcas*, *Pongamia glabra* (karanja), *Madhuca indica* (Mahua), *Salvadora oleoides* (Pilu), cotton seed oil, Tobacco, Calophyllum inophyllum, Eruca Sativa Gars, terebinth, rubber seed oil, desert date, fish oil, Jojoba, neem oil, leather pre-fleshings, apricot seed, Pistacia chinensis Bunge Seed, sal oil, *Moringa oleifera* and *croton megalocarpus*. In addition to the crops oil, microalgae, terpenes, waste cooking oil and animal fats are also used for biodiesel production [14,15]. Different countries have different potential biodiesel feedstock. For example, Rapeseed is the main biodiesel source in Europe, whereas soybean oil is the most common source for biodiesel production in the US, Argentina, and Brazil. Meanwhile, Malaysia and Indonesia pro-

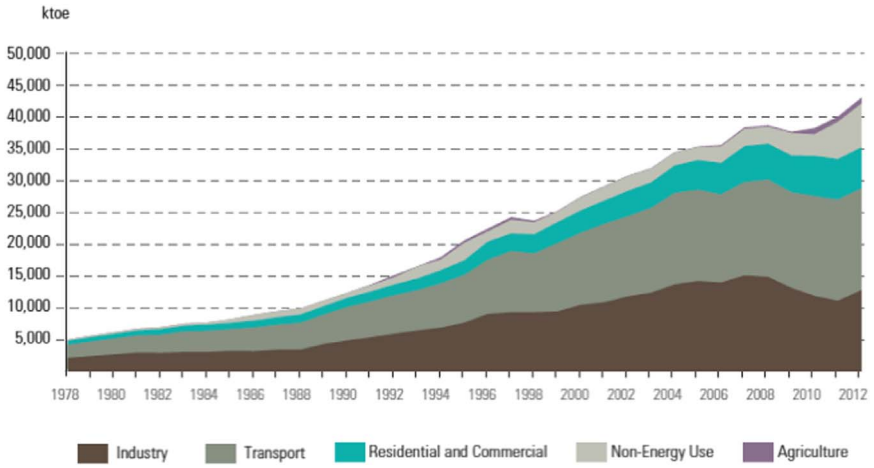

Fig. 2. Energy consumption by sectors in Malaysia [5].