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Review

Implementation of palm biodiesel based on economic aspects, performance, emission, and wear characteristics

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ABSTRACT

The high cost of energy supplies and the growing concern over the dependency on fossil fuels have impelled many countries to search for renewable and alternative energy sources. The extensive use of fossil fuels for transportation and power generation all over the world have caused the supply of fossil fuels to continuously decrease and have aggravated environmental pollution. Searching for alternative fuels has become imperative to reduce pollution and address the problems on fossil fuels. Vegetable oil fuels, such as palm oil biodiesel, serve as alternative forms of energy and are currently being studied, particularly as a diesel fuel substitute. The purpose of this study is to review the potential of palm oil as an energy source and alternative diesel fuel in terms of its performance, environmental impact, wear characteristics, and economic considerations. Compared with other vegetable oils, palm oil is a relatively sustainable, environment-friendly, less expensive, and economically beneficial potential source of energy. Palm oil plantation and production is a major industry in Malaysia, contributing to the economic growth and development of the country. The properties of palm oil biodiesel, namely, high oxidation stability, good cold properties, cetane number, and higher viscosity, makes it a suitable diesel substitute. Compared with other vegetable oils and petroleum diesel fuels, palm oil is associated with better engine performance, higher specific fuel consumption, and shorter ignition delay. Use of palm oil also reduces exhaust emission of hydrocarbon, carbon monoxide, carbon dioxide, and smoke, but not oxide of nitrogen emissions. The higher viscosity of palm oil improves its lubricating properties and anti-wear characteristics, which are favorable for various engine components. Therefore, the aim of this study is to review various studies on palm biodiesel production from different countries and compare the findings of these studies with the situation in Malaysia. This study examines the economic aspects of using palm oil, as well as its effects on performance, emission, and wear characteristics. Palm biodiesel could be the candidate with the greatest potential in all aspects.

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1. Introduction

The decrease in the amount of available fossil fuels and the increase in air pollution from their combustion have prompted a search for alternative fuels and better combustion technology. Since 1977, many countries have taken various steps to reduce their dependency on imported oils. Numerous studies explored alternative fuel resources and measures on how to use energy in the most efficient way. In addition to the depletion of petroleum resources, the increasing stringency of environmental regulations to reduce emissions have accelerated the search for alternative fuels. Environmental pollution has been a growing concern and the effect of global warming has amplified [1–4]. Utilizing non-petroleum oil and domestic resources of energy has increased the self-reliance of countries. This strategy is adopted by the Malaysian government. Currently, energy conservation and the search for alternative fuels are given high priority. In particular, biodiesel has been considered in energy planning as a potential alternative diesel fuel [5,6]. After several years of finding ways to improve diesel engines, such engines are almost fully developed and fuel economy has been improved considerably. Therefore, the exhaust emissions of greenhouse gases from diesel engines have been reduced. Compared with petroleum fuel, alternative fuels are proven more effective when used in diesel engines. Biodiesel is a greener alternative to fossil fuel because it can reduce emissions; thus, it is more beneficial to the environment and to human health [7,8].

Vegetable oils are converted into biodiesel, which is well suited for diesel engines. Its low impact on the environment and economic benefits are the major reasons for the use of biodiesel. Vegetable oils are nontoxic sources of renewable energy and do not contribute to global carbon dioxide (CO_2) buildup. Therefore, vegetable oils as fuels have been studied extensively in recent years [9–12]. Rahman et al. [13], investigated palm oil as one of the vegetable oils widely used as a diesel fuel alternative. Other studies on alternative fuels that investigated the use of coconut [14,15], moringa [16], peanut [17], soybean [18,19], and rapeseed oils generated positive results [20].

The possibility of utilizing biodiesel as a diesel fuel alternative has been known since 1892. Vegetable oils have been studied as diesel fuel substitutes and energy sources all over the world. In the European Union (EU), methyl esters from vegetable oils are called "biodiesel fuel." Rapeseed oil methyl esters are produced and marketed as "biodiesel" vehicle fuel in the EU, especially in France, Austria, and Germany [21–23]. In Malaysia, the performance and technical aspects of soybean, rapeseed, jatropha, coconut, and palm oils as alternative fuels for diesel engines have been studied [24].

Rakopoulos et al. [25], observed that vegetable oils have high viscosity rates and are incompatible with lubricating oils normally used in diesel–fueled engines. Pyrolysis products form and lead to injector nozzle and piston fouling. Such fouling affects the fuel injection system, engine compression, and fuel combustion and consequently affects emissions. Compared with diesel fuels, vegetable oil fuels have lower emissions of oxide of nitrogen (NO_x), Carbon dioxide (CO_2), and hydrocarbon (HC) [26]. Thus, the use of vegetable oils in existing diesel engines is highly expedient. Transesterification is conducted to produce biodiesel from vegetable oil with alcohol [27]. The resulting vegetable oil methyl esters are expected to increase in importance in the future and exhibit potential technological success; internal combustion (IC) engines using palm oil methyl esters have proven the efficiency of this alternative fuel, under certain conditions, for transport and commercial vehicles [28,29].

Öztürk [30] studied biodiesel as fuel for indirect injection (IDI) diesel engines. However, the results showed that substituting diesel fuel with biodiesel without an engine substation cannot be altered, used, or modified by the engine itself. Furthermore, environmental pollution levels are lower when biodiesel is used instead of diesel fuel. A study should be conducted to assess the suitability palm oil fuel blends for IC engines. Fuel of 100% palm oil was also studied in Australia in 1982. The Primary Energy Investigation Unit of James University in Queensland investigated the thermal efficiency of palm oil and its products as compression ignition fuels in a petroleum diesel engine. In an industrial scale, diesel fuel made from palm oil blended with gas oil was prepared at the National Chemical Laboratories and generated satisfactory results [31]. In India, diesel engines are mostly used for transport and agriculture machinery. Palm oil methyl esters (POME) as a diesel fuel blend was used in a direct ignition (DI) diesel engine and generated positive results as an alternative fuel [32].

Benjumea et al. [33] observed the following important combustion parameters: fuel injection timing, cylinder gas pressure, heat release, combustion temperature, and combustion duration. A study on the combustion characteristics of palm oil showed that poor ignition quality is due to the unacceptable atomization of the higher viscosity fuel. To overcome these problems, methods such as micro emulsion, transesterification, and improved engine and fuel system design have been proposed. The heating value of palm oil biodiesel is lower than that of conventional diesel fuel for diesel engines. Palm oil allowed for shorter ignition delay when the biodiesel contents are increased in blends. The emission parameters of greenhouse gases, except for NO_x, decrease with the addition of biodiesel in blend ratios; NO_x increases because of a shorter ignition delay [34–36].

Numerous investigations on palm oil as a diesel fuel substitute have presented the tribological, environmental, and economic aspects of using this type of oil. The objective of the current paper is to review the use of palm oil as an alternative fuel in Malaysia. To this end, the economic considerations, engine performance, exhaust emission, and wear characteristics of palm biodiesel are discussed in this paper.

2. Reasons for using palm vegetable oil fuel as alternative fuel

The full utilization of fuel from vegetable oils as an alternative fuel is constrained by the following considerations:

- Vegetable oils can make only a marginal contribution to the fuel supply worldwide.
- Vegetable oil fuels could only acquire a significant share of the fuel market under certain local conditions (e.g., in Malaysia, some EU countries, and the US).
- Fluctuations in the world market price of vegetable oil complicate the assessment of the economic viability and the availability of vegetable oil fuel compared with conventional fuels [37].

Misra and Murthy [37] noted that vegetable oil fuel can be used for diesel engines for the following reasons:

- Vegetable oil is biodegradable and nontoxic.
- Knocking tendency is lower because of the reasonable cetane number of vegetable oil fuel.
- This type of fuel contains a low amount of sulfur; thus, it is environment-friendly.
- Modifying the major components of diesel engines is not required because of the enhanced lubricity of vegetable oil fuel.
- The flash point of vegetable oil is higher than that of diesel; thus, safety is improved.
- This type of oil is completely compatible with conventional diesel and alternative fuel.
- It results in low emission and noise.