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Fuel properties, engine performance and emission characteristic of common biodiesels as a renewable and sustainable source of fuel

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ABSTRACT

The energy security concern has been established as an alarming issue in context of petro diplomacy now-a-days. Global warming with rapid changes in climate, increase in price and depletion in reserve of fossil fuel are leading scientists to work toward alternative fuel. Biodiesel could be an answer for the alternative fuel, which is renewable, biodegradable, non-toxic and less polluting. This paper is comprised of fuel properties, engine performance and emission characteristics of commonly used different vegetable (jatropha, palm, coconut, cottonseed, sunflower, soybean and canola/rapeseed) based biodiesel derived from experimental results at different conditions performed worldwide. It can introduce a potential guideline to improve engine performance and emission characteristics using different biodiesels and their blends as well. This paper provides a comparative baseline to make an easy comparison among the biodiesels in respect of fuel properties, engine performance and emission characteristics.

Contents

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1. Introduction

The world is moving towards an energy crisis because of the depleting reserve of fossil fuels. In addition, the rapid rise in the use of fossil fuel is favoring this depletion. Besides, increasing fossil fuel price, emission of greenhouse gases and the security and diversity of energy are tending the scientists to turn their attention to find out alternative sources of fuel. Biodiesel is one of the best sources of alternative fuel [1]. It is renewable and clean fuel for diesel engines [2,3]. It is also called environment friendly as it is nontoxic, biodegradable, safer to breathe and emits less greenhouse gases [3].

Biodiesel, as an alternative fuel for internal combustion engines, is defined as a mixture of mono-alkyl esters of long chain fatty acids (FAME) derived from a renewable lipid feedstock, such as vegetable oil or animal fat. Biodiesel typically comprises alkyl fatty acid (chain length C14–C22) esters of short-chain alcohols, primarily, methanol or ethanol [3,4]. Biodiesel is the best candidate for diesel fuels in diesel engines. Production of biodiesel is not a modern invention. The first diesel engine developed by Rudolf Diesel in 1900, was run with groundnut oil [5]. In 1912, Rudolf Diesel also stated that in future the vegetable oils would be an important fuel like petroleum [6]. The awareness about environment is making Rudolf Diesel's prediction true today [5].

Vegetable oils are being used as alternative fuel for more than 100 years after the invention of diesel engine [7]. Depending upon environmental condition, the sources of biodiesel vary from country to country like soybean for North America, sunflower and rapeseed for Europe, palm for Southeast Asia, coconut for tropic and sub-tropic area etc. [8]. However, crude vegetable oils are inferior as fuel in terms of viscosity, heating value, freezing point, etc. Different chemical treatment like transesterification can improve the fuel properties [9,10]. The transesterified vegetable oils are widely being used at present.

Diesel engine has got popularity for its higher thermal efficiency as well as high power to weight ratio. Therefore, it is being widely used in automobiles, power generation and industrial sectors. The diesel power vehicles have about one-third share of total vehicle sold in Europe and USA [11]. However, more stringent emission regulations imposed by the authorities limit its use. Thus, cleaner emission property of biodiesel gives hope for its wide use in diesel engine. It can be used directly in the existing diesel engines without any modification [12,13]. A lot of research efforts have been given on production of biodiesel as well as engine performance and emission characterization [14–23]. Most of them found relatively poor fuel property of vegetable oils and their biodiesels. The brake power and the brake torque of the engine using crude vegetable oil and their biodiesel were relatively lower than that of ordinary petroleum diesel [24–37]. But in some cases the brake thermal efficiency was higher [24,33,38–60]. Again biodiesel blends sometimes gave better brake power and torque than ordinary diesel. On the other hand, biodiesel and its blends improve emission characteristics with exception in case of NO_x [52,61–66]. However, many researchers also found relatively lower NO_x emission using biodiesel and their blends [67–74].

In this study, peer reviewed articles of highly rated journals of seven commonly used biodiesels (jatropha, palm, coconut, cottonseed, sunflower, soybean and canola/rapeseed) have been reviewed. This report focuses on comparison fuel properties, engine performance and emission characteristics of seven biodiesels in a single platform. Each of them is discussed elaborately in different sections. Finally different research results are presented in tabular form in order to have an easy comparison among them.

2. Fuel properties

Density, viscosity, heating value, flash point, acid value, pour point, cetane number, etc. are considered as the most important properties of a fuel for its application in engine. These properties indicate the quality of the fuel. Engine performance and emission are also directly related to these. There are different types of standard like ASTM, EN, ISO, etc. to define the limit of each of the fuel properties. Among them ASTM is the most widely followed standard. To meet the standard engine performance and emission, the value of the fuel properties must be in the range. In this regard study of fuel properties are the most important part to use any liquid as fuel. Now-a-days, blending is widely being used to improve biodiesel fuel properties. Sometimes biodiesel from two or more feedstock are blended to improve the properties. Use of more feedstocks can easily improve fuel properties rather than two because most of the important fuel properties like density, kinematic viscosity, oxidation stability, flash point, calorific value and cetane number vary linearly in case of multiple fuel blends [75–79]. The most widely used vegetable based biodiesel fuel properties are discussed. Table 1 contains fuel properties of seven discussed vegetable based biodiesels.

2.1. Kinetic viscosity

Fuel flow, spray and atomization characteristics are directly governed by the kinetic viscosity of the fuel. Higher viscosity increases fuel pump power consumption and causes poor spray and atomization [76,110,111] and also increases fuel consumption [41]. In these respects, lower viscosity is desired.

From Table 1 most of the biodiesels have higher viscosity than OD (ordinary diesel). But viscosity of palm and coconut based biodiesel are comparable to OD. Therefore, palm and coconut biodiesel can give improved atomization and lead to better combustion than others.

Table 1
Fuel properties of ordinary diesel and common vegetable based biodiesel [3,33,38–41,43–47,49,51,53–60,77,80–109].

Properties	Kinetic viscosity 40 °C (cSt)	Density (kg/m^3)	Cetane number	Calorific value (MJ/kg)	Flash point (°C)
ASTM limit	1.9–6	–	47 minimum	–	130 °C minimum
Diesel	2.5–5.7	816–840	45–55	42–45.9	50–98
Jatropha	3.7–5.8	864–880	46–55	38.5–42	163–238
Palm	2.95–4.92	843–890	49–65	38.73–40.39	135–259
Coconut	2.61–4.1	844–930	51–60	35–38.1	112–241.5
Cottonseed	4–4.9	874–885	51.2–55	40.32–42.73	70–110
Sunflower	4.5–5.9	877–882	49–52	39.7–40.56	85–178
Soybean	4.08–4.97	884–896	40–53	38.31–39.76	69–144
Canola or rapeseed	4.2–4.5	837–886	49–52.9	36.55–40.5	94–183