Renewable and Sustainable Energy Reviews 94 (2018) 772–778

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Biodiesel derived from corn oil – A fuel substitute for diesel

T. Balamurugan*, A. Arun, G.B. Sathishkumar

Department of Mechanical Engineering, Arasu Engineering College, Kumbakonam 612501, Tamilnadu, India

ARTICLE INFO

Keywords:
Corn oil
Biodiesel
Performance
Combustion
Emission
Blended fuels

ABSTRACT

In present scenario, consumption of energy is steadily increasing in all sectors due to increase in population and improved lifestyle. Ever growing demand for energy results in increasing of dependency over fossil fuels. The depleting nature of such energy sources and increasing nature of energy demand are causing serious energy concerns about the future energy security. Use of biodiesel may be one of the solutions to overcome the future energy demand, and production of biodiesel is an interesting avenue for researchers. In this research work, since corn oil has comparable properties of diesel, an attempt was made to produce biodiesel from corn oil and evaluate the performance, combustion and emission characteristics of diesel engine using corn oil biodiesel blended with diesel at different proportions as fuel. The outcome of this research work revealed that the production of biodiesel from corn oil is possible and the experimental observations resulted in a comparable performance, combustion and emission parameters with those of diesel.

1. Introduction

Diesel engine is an essential in today's life. But it contributes to the atmospheric pollution substantially. A solution for reducing the environmental pollution and energy shortage can be envisaged by a paradigm shift from the use of fossil fuel to renewable energy sources. Vegetable oils can be an important alternative to diesel oil, since they are renewable and can be produced easily in rural areas. The inventor of diesel engine, Rudolf Diesel confidently predicted that the plant based oils would be widely used to operate diesel engines. This work was aimed at to produce a biodiesel from corn oil and to study the performance, combustion and emission characteristics of a diesel engine by using corn oil biodiesel blended with diesel at different proportions as fuel.

In general, the choice of vegetable oil as engine fuel predominantly depends upon the local conditions and prevalent availability of a particular vegetable oil in excess amount. Various vegetable oils are being considered worldwide as fuel substitute in the engines; these include karanja oil, cotton seed oil, rice bran oil, sunflower oil, soyabean oil, rape seed oil, madhuca latifolia oil, jatropha oil, etc.

Numerous researches have already been carried out to enhance the performance and to reduce the emission by using different approaches such as using neat biodiesel, mixing different biodiesels with diesel at various proportions, incorporating some design changes in fuel supply system and in combustion chamber, and adding different additives with diesel.

Biofuel development has gained the attention of researchers in recent years owing to the rate of depletion of fossil fuels [1]. Vegetable oil is marked to be a potential source of energy that can substitute fossil fuels because of its comparable properties to diesel fuel, it is renewable and it is readily available [2]. Many experimental investigations have been conducted by using vegetable oils as fuel in diesel engines. The challenges associated with biofuel production and how they relate to sustainable development goals and their targets were focused by Andre M.N. 2017 [3]. The experimental investigations using different vegetable oils as fuel concluded that, there was a considerable reduction in thermal efficiency and NO_x emission, and increase in CO and HC emissions. In some investigations, the use of diesel blended with different vegetable oils reported that there was a reduction in exhaust gas temperature and NO_x emission with a slight increase in CO emission [4]. The use of palm oil as fuel in compression ignition engines concluded that the short term use of palm oil will improve the performance and emission levels considerably and the prolonged use will cause the carbon deposition and sticking of piston rings. The use of corn oil as fuel resulted in the reduction in filter clogging problem [5], also improved the engine performance and reduced the carbon deposits (Murayama T., 1984). The use of cotton seed oil as fuel, without doing any modifications in the engine, concluded that the engine parameters needed some readjustments for getting maximum output power and highest thermal efficiency [6].

The experimental investigations by using honge, neem and sesame oil methyl esters as fuel reported that the performance and emission characteristics were almost similar to those of the engine using diesel as fuel [7]. The higher viscosity of biodiesel caused a reduction in engine

* Corresponding author.
E-mail address: thillaibala@gmail.com (T. Balamurugan).

https://doi.org/10.1016/j.rser.2018.06.048
Received 20 April 2017; Received in revised form 14 March 2018; Accepted 20 June 2018

power; also the lower calorific value of biodiesel increased the specific fuel consumption and decreased the combustion temperature [8]. The use of biodiesel derived from rice bran oil reported the increase in NO_x emission because of the existence of molecular oxygen in bio-diesel, and suggested the exhaust gas recirculation technique for reducing NO_x emission even though the exhaust gas recirculation increases the brake specific fuel consumption and the emission of CO, HC and particulate matters [9]. The experiment on diesel engine fueled with methyl esters of waste pork lard and diesel blends resulted in the reduction in NO_x emission from the engine [10]. The experimental study on diesel engine using linseed oil and mahua oil blended with diesel as fuel, reported that the blending of 50% linseed oil with diesel increased the smoke density and decreased the brake specific energy consumption. The mixing of 30% mahua oil with diesel reduced the smoke density and increased the thermal efficiency [11].

The modifications in engine received significant consideration among the engine researchers to enhance the performance and combustion characteristics, and to reduce the emission from the diesel engine. The introduction of exhaust gas recirculation technique reduced the NO_x emission to some extent [12]. Some experimental investigations based on advancing the injection timing and increasing the injection pressure reported significant increase in brake thermal efficiency and decrease in the emission of CO, HC and smoke [13].

In recent years, remarkable focus is given for the use of alcohols as additive or blend with diesel. The use of alcohols along with diesel had its own complication because of their high latent heat of vaporization and long ignition delay period [14]. However, it was concluded that considerable reduction in exhaust emissions could be achieved by blending alcohols with diesel in proper proportions [15]. The bioethanol derived from vegetable oils was focused as suitable alternate fuel due to its better spark characteristics and high cetane number values [16]. The blending of mahua oil methyl ester with diesel greatly reduced the NO_x emission [17]. The blending of alcohol with diesel concluded that the cumulative heat release rate and brake thermal efficiency were increased with a decrease in NO_x emission [18]. The blending of alcohol with diesel resulted in an increase in HC and smoke emission [19]. The use of biodiesel blended with alcohols concluded the increase in brake thermal efficiency and decrease in CO, HC and NO_x emissions [20]. Some experimental studies using oxygenate additives concluded the increase in brake thermal efficiency and decrease in CO, HC and smoke emissions [21].

From the previous studies, it is evident that various problems were associated while using vegetable oil in compression ignition engines. They are mainly caused by the high viscosity value of the vegetable oils. This high viscosity is due to free fatty acid present in the oil. This free fatty acid is due to large molecular mass and chemical structure of vegetable oil, which in turn leads to problems in pumping, combustion and atomization in compression ignition engines. Hence, it is necessary to reduce the free fatty acid and viscosity of vegetable oil in order to make it suitable as an alternative fuel for diesel engine. The various methods such as transesterification process, pre heating the oil, blending with diesel, use of additives, pyrolysis were adopted to use vegetable oil efficiently.

In this research work, bio diesel was prepared from corn oil by using transesterification process. Before transesterification process, some amount of free fatty acid present in the corn oil has been estimated in the presence of monoglycerides and triglycerides. In this process the triglycerides in the corn oil were converted into their mono ester by reacting with alcohol in the presence of a potassium hydroxide (KOH) as the catalyst. Then the performance, combustion and emission characteristics of the diesel engine were evaluated by using corn oil biodiesel as a fuel blend with diesel.

2. Production of biodiesel

Transesterification also called as alcoholysis is the displacement of alcohol from an ester by another alcohol by a process similar to hydrolysis.

This process has been extensively used to reduce the viscosity of triglycerides. The transesterification reaction is represented by the general equation,

$$\text{R COOR}' + \text{R}'' \rightarrow R\ \text{COOR}'' + \text{R}'\text{OH}$$

If methanol is used in the above reaction, it is formed as methanolysis. The reaction of glyceride with methanol is represented by the general equation. Triglycerides can be easily transesterified in the presence of an alkaline catalyst at atmospheric pressure and at a temperature of approximately 70 °C with excess of methanol. The mixture at the end of the reaction is allowed to settle completely. The lower glycerol layer is drawn off while the upper methyl ester layer is washed to remove entrained glycerol and is then processed further.

The surplus methanol is recovered by distillation and sent to rectifying column for purification and recycling. The transesterification works well when the starting oil is of light quantity. However, poor quality oils are widely used as raw materials for the preparation of biodiesel. In cases where the free fatty acid content of the oil is above 4%, complexity may arise due to the formation of soaps which support emulsification during the water working stage and at a free fatty acid content of above 2%, the process becomes not viable.

If the free fatty acid content of the oil is below 4%, single stage process is adopted. If the free fatty acid content is greater than 4%, double stage process is required. The most important variables that influence transesterification reaction time and conversion are oil temperature, reaction temperature, ratio of alcohol to oil, intensity of mixing and purity of reactants.

Fig. 1 shows the various processes and stages involved in the preparation of corn oil biodiesel.

In this research work, the corn oil was taken in a stainless steel reactor and it was heated to 65 °C with the help of an electric heater and was stirred by using a mechanical stirrer. The required amount of sulphuric acid and methanol were added to the raw oil, and the mixture

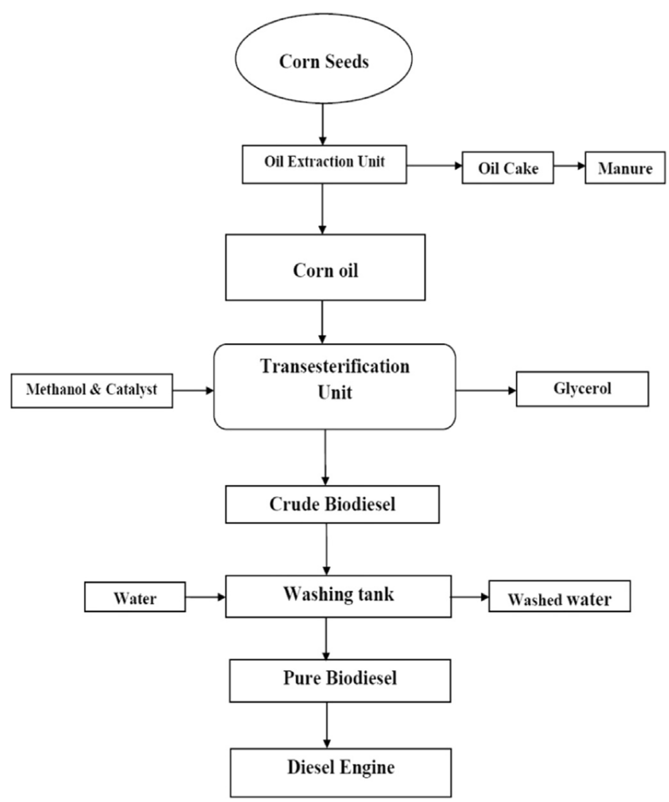

Fig. 1. Preparation of Biodiesel.