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Environmental effect of CI engine using microalgae methyl ester with doped nano additives

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ABSTRACT

Algae are organisms that grow in marine environments and use carbon dioxide and light to create bio-mass. There are two groupings of algae: microalgae and macroalgae. Macroalgae are the large, multi-cellular algae often seen growing in ponds. Microalgae, on the other hand, are tiny, unicellular algae that normally grow in suspension within a body of water. Algae oil from microalgae has the possible to become a sustainable fuel source as biodiesel. Microalgae are produced through photosynthesis by utilizing sunlight, water, carbon dioxide and other nutrients. The *Botryococcus braunii* algal oil was extracted by mechanical extraction method. The transesterification reaction of *Botryococcus braunii* algal oil with methanol and base catalyst was used for the production of biodiesel. The samples B20 were prepared for each methyl ester obtained from *Botryococcus braunii* algal oil separately and then the doping of TiO_2 and SiO_2 nanoparticles were added to the each B20 blend samples at a dosage of 50 ppm and 100 ppm with an aid of ultrasonicator. Moreover, in the absence of any engine modifications, the performance and emission characteristics of those blend samples have been investigated from the experimentally measured values such as density, viscosity, calorific value, etc. while the engine performance was also analyzed through the parameters like BSFC, BTH, exhaust emission of CO, HC, NOx and CO_2. The experimental results reveal that the use of biodiesel blend with nano additives in diesel engine has exhibited good improvement in performance characteristic and reduction in exhaust emissions.

1. Introduction

World energy demand increases gradually which mainly comes from the non-renewable resources. The energy resources are limited and reduce simultaneously due to the high consumption of energy. More energy consumption leads to poisoning our environment. Due to these two main reasons worldwide engineers and scientist engineers giving attention to find new,

Abbreviations: CO, carbon monoxide; HC, hydrocarbon; NOx, oxides of nitrogen; TiO_2, titanium dioxide; SiO_2, silicon dioxide; CO_2, carbon dioxide; BBOME, *Botryococcus braunii* oil methyl ester; FAME, fatty acid methyl esters; NAOH, sodium hydroxide; FFA, free fatty acids; rpm, revolutions per minute; B20, 80% diesel + 20% BBOME; B20$TiO_2SiO_2$50, 80% diesel + 20% BBOME + 50 ppm of doping of TiO_2SiO_2; B20TiO_2SiO, 80% diesel + 20% BBOME + 100 ppm of doping of TiO_2SiO_2; BSFC, brake specific fuel consumption; BTE, brake thermal efficiency; ITE, indicated thermal efficiency; BMEP, brake mean effective pressure; LHV, low heating value; CI, compression ignition; FT IR, Fourier transform infrared; $FeCl_3$, ferric chloride; FBC, fuel borne catalyst.

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ecofriendly and renewable energy resources which can meet the energy demand without harming the environment. A lot of efforts have been made to search the alternative energy resources. A lot of research efforts have been going on to meet the task of the environment protection and fuel demand simultaneously. The researchers are involved with finding new such resources and trying to exploit them to attain environment friendly alternate energy resources. Very recently scientists proposed microalgae as one of such resources. This resource seems to be a low potency product but its growth rate and cost of production are the main reasons that scientists are paying massive attention. Algae have ability to convert CO_2 into oil through photosynthetic process (Sharif Hossain et al., 2008; Chisti, 2007; Mata et al., 2010).

1.1. Microalgae

Microalgae are the ancient living microorganism survived over 2.5 billion years. These are unicellular and their reproduction rate is very fast utilizing environmental CO_2, sugar and sun light that can produce proteins, lipids and carbohydrates in large amounts over short period of time. Scientists and engineers are involved with developing technologies that can help in translating this biomass into diesel economically. The microalgae have some significant advantages to be used as a biodiesel feedstock such as these are cultured to act as a low cost raw material, contain high energy per unit mass, renewable, environmentally friendly and can contribute to reduce CO_2 levels in the atmosphere by consuming for its own reproduction it and converting it to diesel oil (Sharif Hossain et al., 2008).

1.2. Botryococcus braunii microalgae

It is a green colonial microalgae which produces high levels of lipids, mainly hydrocarbons and ether lipids. Metzger defined as lipids of all compound readily soluble in organic solvents but only sparingly soluble in water. It is an algae that forms colonies (Metzger and Largeau, 2005). The sizes of these colonies have a wide range with volume average diameters ranging from 0.05 to 0.2 mm and are strongly dependent on light intensity in the experiments (Zhang et al., 2007). It contains lower contents of phosphorus and nitrogen than many other algae on an organic basis, therefore the energy requirement for fertilizers are smaller (Tsukahara and Sawayama, 2005). It strains can be found in all climate zones except the antarctic. There are three races, A and B which grow in alpine, continental, temperate and tropical lakes and L which has only been found in tropical conditions. The classification into different races depends on the HC production. Race A produce C23-C33 odd numbered *n*-alkadienes, from mono- to tetraenes, where oleic acid is found to be precursor of the dienes and trienes. Race L produce only lycopadiene, which is a tetraterpenoid hydrocarbon. Algae of race B produce polymethylated triterpenoid hydrocarbons, called botryococcenes which range from C30 to C37. Other hydrocarbons, which the B race synthesizes in trace amounts, are squalene and C31-C34 methylated squalenes. HC contents of up to 61% in algae of race A have been discovered. Race B usually gives HC contents of 30–40% while the L race has a HC content of maximum 8% (Mata et al., 2010).

The growth related HC production is a special feature of *Botryococcus braunii*, compared to many other microalgae like Chlorella, which mainly produce fatty acids during nitrogen starvation (Eiichi and Kai, 1999). In fact HC production does not take place during nitrogen and phosphorus starvation of *Botryococcus braunii* (Casadevall et al., 1985). Chirac et al. factors important for growth are CO_2, light, nutrients and water, as well as temperature conditions and pH (Chirac et al., 1985). Several studies have been performed on *Botryococcus braunii* to investigate the ability to affect growth rate and HC yield by changing different parameters. It has been showed that air enriched with 1% CO_2 enhances growth; the doubling time of the biomass was approximately 2.7 days instead of about 7 days with non-enriched air. HC production also increased five times with CO_2 enriched air (Wolf et al., 1985). It requires light intensities in the range 40–90 W/m^2 for optimal HC production (Cepak and Lukavsky, 1994; Li and Qin, 2005). It has been reported that *Botryococcus braunii* accepts irradiances between 15 and 180 W/m^2. The slow growing Japanese strain that was not affected in growth or lipid content at the irradiance 300 W/m^2. Studies on *Botryococcus braunii* indicate that to achieve optimal growth the temperature of the medium should be around 25 °C. Li et al. made a comparison between three different strains from temperate to subtropical climate zones which all exhibited optimal growth at 25 °C (Li and Qin, 2005).

1.3. Biodiesel in CI engines

Biodiesel can be derived from vegetable oils with edible and non-edible grade, waste vegetable oils as well as from animal fats which offer many novel advantages that make biodiesel in general an attractive proposition for unaltered CI engines. Vegetable oil based ester fuels can be derived from a number of edible, nonedible grade oil sources such as peanut, sunflower, palm, soybean, sesame, rapeseed/canola, mustard, sunflower, linseed, coconut, jatropha curcas, karanjia (*Pongamia glabra*), *Pongamia pinnata*, mahua, neem, pine seeds, tung seeds, nagchampa, kusum, etc. (Anpu et al., 2011). Harinathareddy et al. investigated the performance of a diesel engine using standard diesel, cotton seed oil biodiesel and jatropha oil in terms of BTE and ITE. A single cylinder, four stroke vertical, air-cooled and self-governed diesel engine was employed for testing at full load conditions. The evaluation of theoretical data showed that the BTE and ITE of cotton seed oil biodiesel were slightly higher than that of the standard diesel and jatropha oil (Harinathareddy et al., 2013). Two diesel engines rated at 14.2 kW (small) and 60 kW (large) were operated by using sun flower methyl ester and its blends with a standard diesel. The results showed that less power and torque were delivered by both the small and large engines when ran on pure sun flower methyl ester than on standard diesel, while BSFC was found to be higher for pure sun flower methyl ester. The blends of sun flower