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Performance and Emission Characteristics on Diesel Engine Using Waste Chicken Fat Oil as Biodiesel

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ABSTRACT: In this paper a two-step catalytic process was chosen for the synthesis of the biodiesel. Methanol, sulphuric acid and sodium hydroxide catalyst were used in the reaction. To determine their effects on viscosity and flash point of the biodiesel, reaction temperature, methanol ratio, type and amount of catalyst were varied as independent parameters. Organic based synthetic magnesium additive was doped into the biodiesel blend by 12 mmol Mg. Engine tests were run with diesel fuel (EN 590) and a blend of 10% chicken fat biodiesel and diesel fuel (B10) at full load operating conditions and different engine speeds from 1800 to 3000 rpm. The results showed that, the engine torque was not changed significantly with the addition of 10% chicken fat biodiesel, while the specific fuel consumption increased by 5.2% due to the lower heating value of biodiesel. In-cylinder peak pressure slightly rose and the start of combustion was earlier. CO and smoke emissions decreased by 13% and 9% respectively, but NOx emission increased by 5%.

Keywords: Waste Chicken fat, Diesel engine, Pressure, viscosity, flash point

I. INTRODUCTION

Investigations on renewable energy resources are continuing extensively due to increasing dependence on petroleum products, the energy crisis, global climate change and environmental pollution. Biodiesel is one of the most used renewable energy sources for diesel engines. Biodiesel blends can be used in diesel engines without any major modification. Projections indicate that environmental hazards, economics and energy needs will increase the emphasis on the production of methyl ester fuels derived from oils or fats. However, biodiesel blends can lead to food shortages and they are not always economic or feasible. Vegetable oils and animal fats are not suitable direct replacements for diesel fuel in engines, boilers or cogeneration systems, due to their inappropriate physical properties such as longer molecule chains, lower pour points, lower vapor pressures, higher viscosities and higher flash points. These features cause poor atomization, poor vapor–air mixing, low pressure, and incomplete combustion and engine deposits. However, it is possible to reduce the viscosity of vegetable oil, improve the physical features of both vegetable oil and animal fat through dilution, pyrolysis, micro emulsion and esterification [1]. Esterification is a kind of catalytic reaction in which oil or fat is reacted with alcohol to form esters (biodiesel). The two types of raw materials used in the biodiesel processes are vegetable oils and animal fatty acids.

Some vegetable oils such as sunflower oil [2,3], olive oil [4,5], pomace oil [6], soybean oil, cotton oil [8], hazelnut oil [9], rubber seed oil , mahua oil, jojoba oil, tobacco seed oil, rapeseed oil, palm oil, tall oil, cooking oil, etc. have been used in biodiesel production. For the purpose of improving biodiesel, organic based magnesium, molybdenum, manganese and nickel additives were synthesized, dosed into the tall oil methyl ester and the performance and emission data were investigated in our early studies. Four types of metallic additives have also been studied for this purpose.

Although vegetable oil esters have certain advantages such as lower viscosity, lower flash point, higher vapor pressure and easier processing relative to animal fatty acid esters, they are noneconomic and non-feasible due to their prohibitive cost. Furthermore, many vegetable oils used in the production of biodiesel are edible oils and hence are valuable. For the same reason, use of edible vegetable oils for biodiesel production leads to food short- ages. On the other hand, animal fats in human food constitute health hazards. This is one of the reasons for their low cost. However, disadvantages presented by their physical properties such as high pour point, high viscosity, high flash point, and processing difficulties must be eliminated with magnesium-based additives to improve the economics and feasibility. Use of nonedible fatty acid waste is an additional advantage.

Thus, biodiesel was synthesized from salmon oil, animal fats, etc. In the present work, we intend to produce methyl ester from the waste chicken fat at optimized conditions and improve the fuel's properties with synthetic magnesium additive, as a novel process. Diesel fuel and a blend of waste chicken fat methyl ester doped magnesium additive with diesel fuel (10%) were tested in a direct injection diesel engine at full load conditions.

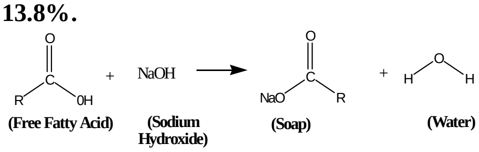
II. HISTORY

- As per the Government of India statistics, approximately 700,000 ton of chicken meat is consumed every year.
- The feather meat contains fat which varies from 2% to 12%
- Hence, about 77,000 ton of chicken fat is available

According to statistics available with the Tamil Nadu Veterinary and Animal Sciences University, the daily average mortality rate of egg laying chicken is 0.03 per cent. "On an average about 4,000 birds die everyday. About 90 per cent of them are disposed of under unhygienic conditions (thrown in the open)," Dr. Abraham noted. Unscientific methods of disposal of carcases leads to pollution of ground and surface water, obnoxious odour and health hazards through indiscriminate breeding of micro organisms and house flies. There are many incidents of conflicts between the poultry farmers and residents over open disposal of dead birds. Calculating the annual mortality rate at 12 lakh birds in this district, he realised the opportunity in the form of extracting fat of dead birds and producing bio-diesel from two different methods. While each bird weighs about 1.5 kg, fat constitutes 14.5 per cent of the bird's weight.

III. BIODIESELPRODUCTION

- **The selection of catalyst depends on FFA content of oil.**
- **The FFA (free fatty acid) content can be determined by using titration method.**
- **FFA < 1% Base catalyst is preferred(One Stage Process)**
- **FFA > 1% Acid catalyst is preferred (Two Stage process)**
- **FFA content of WCF was found to be 13.8%.**



IV. WORKING PROCEDURE

Engine test apparatus and method

The experimental study was conducted on a single-cylinder, four-stroke DI diesel engine. The general specifications of the test engine are shown in Table 1. A Cussons P8160 type standard engine test bed which consists of an electrical dynamometer was used. The electrical dynamometer is a swinging field direct current (DC) apparatus rated for 10 kW power absorption at 4000 rpm operating speed. The engine load was measured with a strain gauge load cell sensor. Engine speed was measured with a magnetic pick-up sensor. The schematic view of the test equipments is shown in Fig. 1. Diesel fuel flow was measured with a high-precision electronic balance. Inlet air, exhaust gas, lubricating oil temperatures were measured with an ELIMKO-6000, multi-point electronic temperature indicator. The thermocouples used were NiCr–Ni type, which can measure up to 1200 C. Cylinder pressure was measured using an AVL 8QP500c water cooled quartz pressure transducer and amplified with Cussons P4110 combustion analyzer charge amplifier channel. A rotary encoder was coupled with the engine crankshaft. A National Instruments USB 6259 data acquisition card was used for recoding signals on triggered mode with 0.36 CA resolution. Mean pressure data were calculated using 50 consecutive cycles. The net heat release rate (NHRR) analysis was calculated according to a single zone combustion model based on the first law of thermodynamics. An MRU DELTA 1600 exhaust gas analyzer was used to measure NOx (CLD), CO (NDIR) and HC (FID). The soot concentration level was measured using a VLT 2600-S partial flow smoke meter. Accuracies of all the measurements and the uncertainties in the calculated results are shown in Table 2. In this study, blends of chicken fat based biodiesel fuel (B10 – blended in volume at the ratio of 10% with diesel fuel) and diesel fuel were evaluated. Magnesium based additive was added into the blend at a ratio of 12 mmol/L. Properties of diesel fuel and test fuel (B10) blended with 12 mmol Mg additive are given in Table 3. Experiments were conducted at full load conditions and different engine speeds varying between 1800 and 3000 rpm in intervals of 200 rpm. Before each test, the engine was warmed up with diesel fuel. Engine oil temperatures were kept stable around 80 C.

V. ENGINE TEST RIG

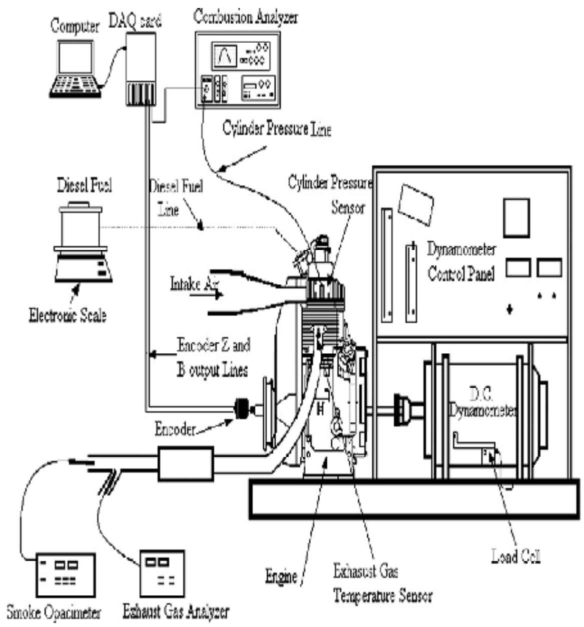
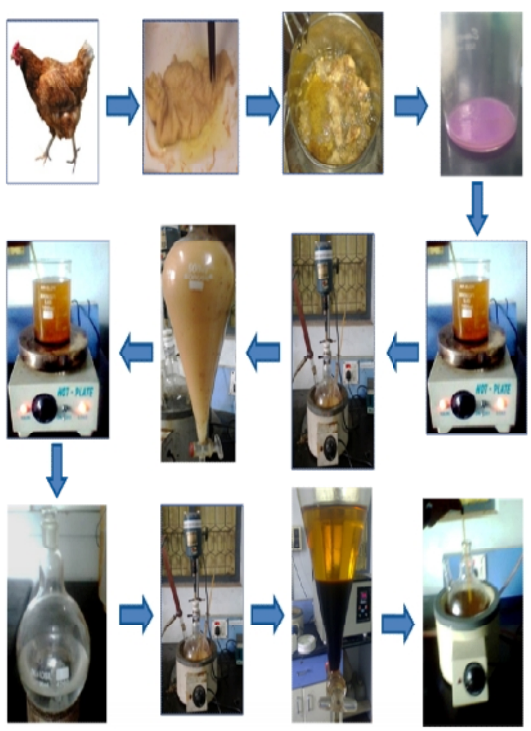


Fig. 1. Schematic diagram of engine test rig.

VI. PHOTOGRAPHIC VIEW OF STEPS INVOLVED IN BIODIESEL PRODUCTION PROCESS



VII. COSTANALYSIS

Process		Amount Rs.
[illegible]	Waste Chicken (5kg)	5
	Electrical Charge	5
Pre-Treatment	Methanol	16
	Catalyst	1.5
	Electric Charge	1.5
[illegible]	Methanol	9
	Catalyst	2
	Electric Charge	1.5
[illegible]	Distillation, Washing, etc	5
Total		46
Diesel (approx)		50

VIII. RESULTS AND DISCUSSION

Effect of temperature on biodiesel properties

Temperature for chicken fat methyl ester reaction is important due to the high melting point of chicken fat. While the reaction temperatures were changed between 40°C and 70°C, other parameters were held constant throughout the experiments, as is explained under Fig. 1. With reaction temperatures 50 1 and 551C, the reaction did not start and the glycerin phase did not form. At 58 1 C, reaction was slow to start and very little amount of glycerin phase was observed at the bottom. Temperature and time are actually interacting parameters in the reaction. This low yield probably is the result of very slow reaction at these temperatures. Hence, the reaction could not be completed in 2 h and these two data points (50°C and 55°C) are not shown in Fig. 2. The yields versus temperatures of 58–68°C are plotted on the graph. Increase in temperature in the range from 62°C to 68°C caused a slight decrease in yield. The probable main reason for this decrease is from the loss of methanol from the liquid phase at higher temperatures due to the vaporization. Decomposition of chicken fat methyl ester at higher temperatures is probably another reason contributing to the falling yield.

Raising the reaction temperature from 62°C to 68°C resulted in a slight increase in 20°C viscosity of the biodiesel: from 6.740mm^2/s to 6.842 mm^2/s. Similarly, increase in the reaction raised the flash point from 136°C to 145°C. Lopez *et al*. recommended 60°C as an optimum temperature for the reaction of larger triglycerides in vegetable oils and fats with methanol. So, the reaction temperature of 62°C, which corresponds to the maximum yield (89% (w/w) by fat) and the lowest viscosity and flash point, was chosen as a constant for the subsequent experiments.

Table 2: Accuracies of the measurements and the uncertainties in the calculated results.

Fuel (g)	Accuracy¼0.5 g
Heating value(kj/kg)	Accuracy¼%0.1
Time (s)	Accuracy¼%0.5
Fuels flow rate(g/h)	Uncertainty¼%0.5
Speed (rpm)	Accuracy¼%1
Load (N)	Accuracy¼%0.25
Torque (Nm)	Uncertainty¼%0.25
Power (KW)	Uncertainty¼%1

XI. THE EVALUATION OF PERFORMANCE, COMBUSTION CHARACTERISTICS AND EXHAUST EMISSIONS

The variations of torque, power and specific fuel consumption with engine speed for diesel fuel and chicken fat based biodiesel are shown in Figure. As can be observed, diesel fuel and B10 have similar trends in engine performance. Maximum engine torque occurred at 2200 rpm engine speed with both types of fuel. Slight differences were observed for torque and power with the addition of biodiesel fuel at higher speeds. However, specific fuel consumption (SFC) increased at all engine speeds compared to the diesel fuel. SFC was increased by 5.2% at the maximum torque speed of 2200 rpm for biodiesel fuel. In general, power loss can be observed with the addition of biodiesel fuel because of its oxygen content and lower heating value when compared with diesel fuel. Heating value of the chicken fat based biodiesel used in this study was approximately 9% lower and its density 2% higher than diesel fuel. In the traditional jerk fuel pump systems, fuel metering is made volumetrically via displacement of a plunger in the hydraulic pump. Therefore, an increase of mass based flow rate in the same fuel volume is due to the higher density of biodiesel. In addition, internal leakage in the pump could be decreased by using more viscous biodiesel fuels. Thus, effects of lower heating value on the torque and power can be compensated somewhat by denser biodiesel fuel. Regarding specific fuel consumption, more fuel mass flow rate is required to provide the same engine output due to lower energy content of biodiesel and this results in higher specific fuel consumption. Figure shows the variations of thermal efficiency with engine speed. As can be seen in the figure, thermal efficiency of biodiesel fuel decreased by 4.8%. Engine thermal efficiency is affected inversely with specific fuel consumption and heating value of the fuel. As shown in Fig. 4, lower thermal efficiency occurred with B10 fuel despite the lower heating value, since, higher SFC has an inverse effect on thermal efficiency.

Similar results had been observed in past studies. In-cylinder gas pressure and heat release rate at full load and 2200 rpm engine speed. As shown, a rapid pressure rise related to the combustion of fuel occurred earlier with biodiesel fuel and maximum cylinder gas pressure was slightly higher than diesel fuel. Maximum cylinder gas pressure was 60.8 bars at 9.72 CA with biodiesel and 59.65 bar at 6.85 CA with diesel fuel. As seen from the heat release rate profile, combustion of biodiesel fuel started approximately 0.72 CA earlier than diesel fuel. The main reasons for this early start of combustion (SOC) is commonly given as the different physical and chemical characteristics of biodiesel fuel such as higher density, viscosity, bulk modulus and cetane number. It is less compressible than diesel fuel and causes earlier fuel injection. Also, the higher cetane number shortens the ignition delay. Therefore, the maximum heat release rate of biodiesel in the premixed combustion was lower than diesel fuel, due to smaller accumulation of fuel during the shorter ignition delay time. After that premixed combustion phase, initial heat release rate during the diffusion combustion was higher and later falling only slightly. This is due to the higher oxygen content of biodiesel which improves oxidation and ensures the completion of combustion in the initial stage of diffusion combustion, which in turn results in higher in-cylinder temperatures. The variation of CO and smoke emissions with engine speed is shown in Figs. 6 and 7. It may be observed that, CO and smoke emissions show similar behavior. CO and smoke emissions were higher at lower engine speeds and decreased gradually with increasing speed due to poorer atomization and air–fuel distribution arising from lower turbulence intensity at low engine speeds. With the addition of biodiesel, CO and smoke emissions decreased at all engine speeds. CO and soot emissions decreased by 13% and 9% respectively, at 2200 rpm. Reduction in smoke emissions is principally based on the oxygen content of biodiesel and lower aromaticity and sulphur content. When the incylinder temperature reaches a certain level, soot formation starts with the fuel pyrolizing process in the fuel rich regions of the fuel spray during the diffusion combustion. With combustion of biodiesel, fuel bounded oxygen enhances fuel oxidation in these regions and that leads to a reduction in the formation of soot precursors. On the other hand, CO emissions are primarily related to the air–fuel ratio in engines.

Advantages

- Less green house gas emissions.
- It is biodegradable and non-toxic
- CO and smoke emissions decreased by 13% and 9% respectively, but NOx emission increased by 5%.
- Specific fuel consumption increased by 5.2% due to the lower heating value of biodiesel.

Disadvantages

- ENERGY OUTPUT-Biofuels have a lower energy output then traditional fuels and therefore required greater quantities to b consumed in order to produce the same energy level.
- HIGH COST:- To refine biofuels to more efficient energy output is high and to build the necessary manufacturing plant have to increase biofuels quantities.
- Not suitable to use at low temperature
- Biodiesel is not distributed as widely as petroleum diesel.

X. CONCLUSION

Due to the health risks of waste chicken oils, it is considered as waste oil by the food industry. Therefore, waste chicken fat is a cheap raw material and its low operating cost in biodiesel production make this study a promising one for possible technological applications. Chicken fat methyl ester blended with diesel fuel can be used as an alternative fuel in conventional diesel engines without any major modification. Low sulphur and aromatic contents are advantages of chicken fat methyl ester–diesel fuel blends. Magnesium based additives reduce the pour point, flash point and viscosity of biodiesel fuel, depending on the rate of additive. The engine tests results showed that the engine torque was not changed significantly with the addition of 10% chicken fat biodiesel, while the specific fuel consumption increased by 5.2% because of the lower heating value of biodiesel. In-cylinder peak pressure slightly rose and the start of combustion was earlier. CO and smoke emissions decreased by 13% and 9%, although NOx emissions increased by 5% with the addition of biodiesel to diesel as fuel. Optimum conditions recorded in this study may be applied to biodiesel production processes economically and this methyl ester blend with diesel may be consumed as an alternative, environment friendly fuel.

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