Performance and Emission Characteristics of Compression Ignition Engine Fueled with Chicken Fat Biodiesel

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***Abstract*— In this present investigation biodiesel was developed from waste chicken fat having high free fatty acids (FFA).Two two step esterification method was used to develop the biodiesel from waste chicken fat. This two-step esterification method consists of pretreatment (Acid esterification) followed by Alkaline esterification. The properties of the biodiesel were measured and compared with petroleum diesel. Performance and emission test was conducted in compression ignition engine with chicken fat biodiesel and its blends, compared with petroleum diesel. For lower biodiesel blends brake thermal efficiency is increasing and specific fuel consumption is decreasing as compared to petroleum diesel. The exhaust gas emissions also reducing for lower biodiesel blends compared to petroleum diesel. The experimental results proved that use of chicken fat biodiesel in compression ignition engine is a viable alternative to petroleum diesel.**

***Keywords*—Fatty acids, Biodiesel, chicken fat, esterification.**

I. INTRODUCTION

In 1895, Rudolf Diesel developed a new engine with the intention that it could use a variety of fuels, including vegetable oil (peanut oil), when he showcased it to the public at the 1900 in Paris. But the diesel engine became more widely adopted in subsequent years, because petroleum-based diesel fuel proved to be less expensive and became the fuel of choice.

However in 21st century investigations on renewable energy resources are continuing extensively due to increasing dependence on petroleum products. Besides, the combustion of petroleum based fuels over the past century has dramatically increased the emission of carbon dioxide and other greenhouse gases in the atmosphere. Concerning environmental damage the transport sector has a clear responsibility. So many researchers have been conducted in worldwide to these problems found that Biodiesel is one of the most renewable energy sources for diesel engines. Biodiesels not only decreasing dependency on petroleum products , also reducing greenhouse gas emissions because these are manufactured from plants, which obtain carbon dioxide from the air during photosynthesis, its use reduces overall CO_2 emissions[1].

Biodiesels are produced from vegetables oils or animal fats having very long chain alkyl esters. Vegetable oil esters have certain advantages such as lower viscosity, lower flash point, 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 and it leads to food shortages. On the other hand, Biodiesel may also be produced from fats, including inedible tallow, pork lard and yellow grease. These are in human food leads health hazards. This is one of the reasons for their low cost. Besides, their high cetane number and heating values are close to the diesel fuel and their oxygen content make animal fats to have surplus advantages [2].

The methodology for developing biodiesel is decided by the FFA content of the feedstock. If the FFA content is greater than 3%, it is not possible to convert as biodiesel using alkaline esterification alone [3], its required pretreatment called Alkaline esterification.

In this present work, a substitute fuel for diesel engines was produced from waste chicken fat, collected from a local slaughterhouse during food preparation process.

II. BIODIESEL DEVELOPMENT FROM WASTE CHICKEN FAT

Waste chicken fat was obtained from a slaughterhouse, at room temperature solid in state, so it was heated at 110^{o}C for 1 to 1½ hours to convert in to the liquid form and sediments were removed using cloth filter. The properties of the fat was measeured. The viscosity of the fat is 39.2 mm^2/s at 400C, so it is not possible use directly in engine, and FFA content is 14.1%.So two step esterification method was adopted to develop the biodiesel. During the pretreatment process (Alkaline esterification) methanol and Sulphuric acid was used.Intially fat is heated to 600C and experimentally optimized methanol to fat ratio of 0.2(v/v) and catalyst(Sulphuric acid) to fat ratio of 0.7%(v/v) is added to the fat and the mixture is continuously stirred using magnetic stirrer for 1 hour. Then it is allowed to settle down for 4 hours. It forms two layers,product is separated and FFA value was determined less the 3%.

The product obtained during the pretreatment was used for alkaline esterification process. Methanol and Potassium hydroxide was used for reaction.Intially the product heated to 60^{0}C and the experimentally optimized methanol to fat ratio of 0.2(v/v) and catalyst (Potassium hydroxide) to fat ratio of 0.7%(w/w) is added and the mixture is stirred continuously at constant speed for I hour and allowed to settle down the for 12 hours in a separating funnel. Two layers were formed as biodiesel at top and glycerol at the bottom. Biodiesel was separated and sent for water wash to remove the unreacted alcohol and glycerol. Gas chromatography test was conducted to find the methyl esters profile and shown in Table 1.

TABLE I.

Methyl Esters Profile of Chicken Fat Biodiesel

Methyl ester	Weight,%
Methyl Meristic	1.1
Methyl Palmitoleic	8.86
Methyl Palmitic	28.63
Methyl Stearic	7.5
Methyl Octadecenoic	53.92

III. CHARACTERIZATION OF CHICKEN FAT BIODIESEL

All the properties of chicken fat biodiesel was measured and obtained within the American society for testing and materials (ASTM) limits of biodiesel and compared with properties of petroleum diesel properties shown in Table 2.

Table II.

Properties of Chicken Fat Biodiesel and Petroleum Diesel

Property	Biodiesel	Petroleum diesel
Specific Gravity	0.879	0.83
Lower Calorific value, MJ/kg	38.45	43.5
Viscosity, mm^2/s @ 40^{0}C	4.73	2.87
Flash point,^{0}C	176	46
Fire point	186	56
Cloud point	-2	-1
Pour point	-3	-16
Acid value, mg KOH/g fat	0.31	-

IV. ENGINE PERFORMANCE AND EMISSION TEST

Performance and emission test was conducted on 4 - stroke naturally aspirated single cylinder diesel engine. The detailed specifications of the engine listed in table 3. To measure the exhaust emission KANE – QUINTOX flue gas analyzer was used. Experiments were conducted for pure diesel and biodiesel blends B10, B20, B40, B70 and B100.the uncertainty of measurements is done as per the root–sum–squared computation method proposed by R.J. Moffat (1985).Calculated uncertainties of different measured parameters are given in table 4.

TABLE III

Specifications of the Engine

Rated power	5 hp
Speed	1500 rpm
Stroke length	110 mm
Bore	80 mm
Alternator capacity	3.5 KVA
Alternator efficiency	75%
Orifice diameter	20 mm
Coefficient of discharge	0.6
Compression ratio	16.5

TABLE IV

Uncertainty of Measured Parameters

Parameter	Units	Value
Time	Seconds	±0.5
Fuel consumption	Kg/hr.	±0.0026
Specific fuel consumption	Kg/kW-hr	±0.04417
Brake thermal efficiency	%	±0.825
Indicated thermal efficiency	%	±0.825
Exhaust gas temperature	^{o}C	±0.15
NOx emissions	Ppm	±5
CO emissions	%	±2.5
HC emissions	Ppm	±6
CO2 emissions	%	±2.5

V. RESULTS AND DISCUSSION

A. Brake thermal efficiency

The variation of brake thermal efficiency with respect to brake power for various biodiesel blends shown in fig 1. In all cases brake thermal efficiency increases with increasing load due to reduction in heat loses and increases in power developed. The maximum brake thermal efficiency obtained was 27.7% for B10, which is higher than the diesel efficiency (26.1%).The maximum brake thermal efficiency obtained for B20, B40, B70 and B100 are 25.1, 24.6,24 and 23% respectively.Intially brake thermal efficiency increases with increasing biodiesel concentration, possible reasons are additional lubricity will be provided and the molecules of chicken fat methyl esters consists of oxygen content helps to have complete combustion. Further increasing biodiesel concentration brake thermal efficiency decreases, B100 give the low efficiency due to reduction in calorific value of 11.6% as compared to diesel.

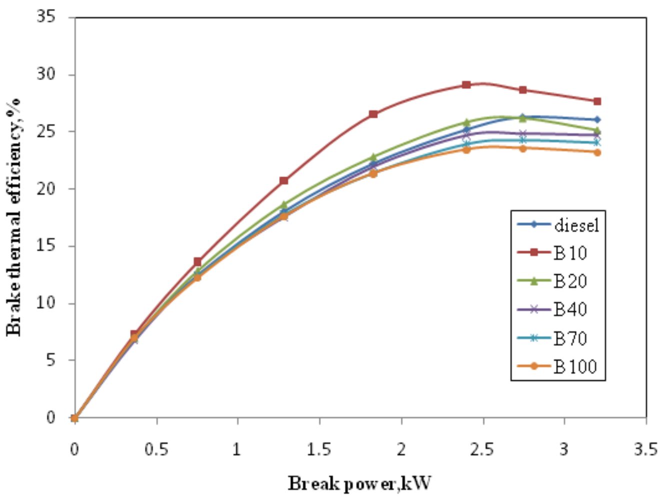

Fig.1. Variation of brake thermal efficiency with brake power

B. Specific fuel consumption

The variation of specific fuel consumption (SFC) with brake power for diesel and different biodiesel blends are shown in fig 2. For all fuels, brake specific fuel consumption is found to decrease with increase in the load. This is due to the higher percentage increase in brake power with load as compared to the increase in fuel consumption. For lower biodiesel concentration (B10) SFC is 5.6% lesser than the diesel .Further increasing the biodiesel concentration SFC is increasing. At the rated load B100 consumes 20.2% more fuel as compared to diesel. The major reason are calorific value of biodiesel is lesser than diesel, and density of the biodiesel is higher, so large amount of fuel is drawn for same volume. Improper mixing of fuel with air also the effect of density leads to increase fuel consumption.

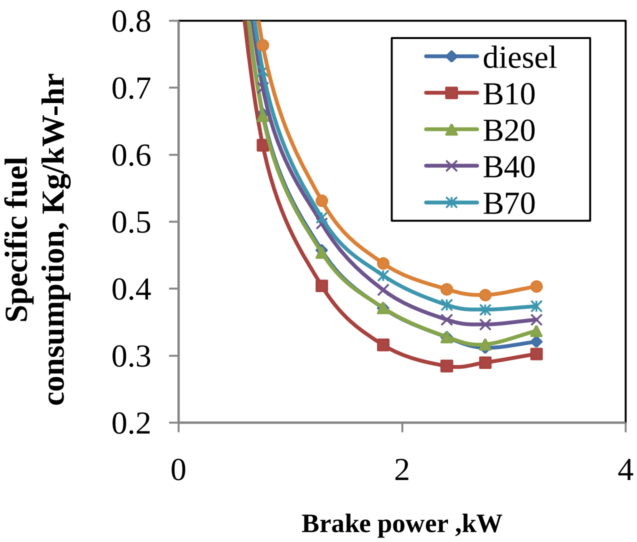

Fig.2. Variation of specific fuel consumption with brake power

C. Air –fuel ratio

Air-fuel ratio is the ratio of mass of fuel to the mass of intake air. The mass of fuel and air are estimated from experimental measurements. Mass of air intake remains almost constant or slightly decreases with increasing load. The fuel consumption increases with load and hence air-fuel ratio decreases with increasing load. This is true with all the fuels. Air-fuel ratio characteristics of pure biodiesel and biodiesel blends are shown in Fig 3. Air – fuel ratio is decreasing with increasing the biodiesel concentration except B10, because lesser fuel consumption than the diesel. The decrease in air-fuel ratio with increasing brake power shows that excess air available for combustion reduces as load increases. This has a direct effect on the degree of completion of combustion. The combustion efficiency reduces as the availability of excess air is less. Also the reduction of excess air availability leads to hazardous emissions like emissions of CO and HC.

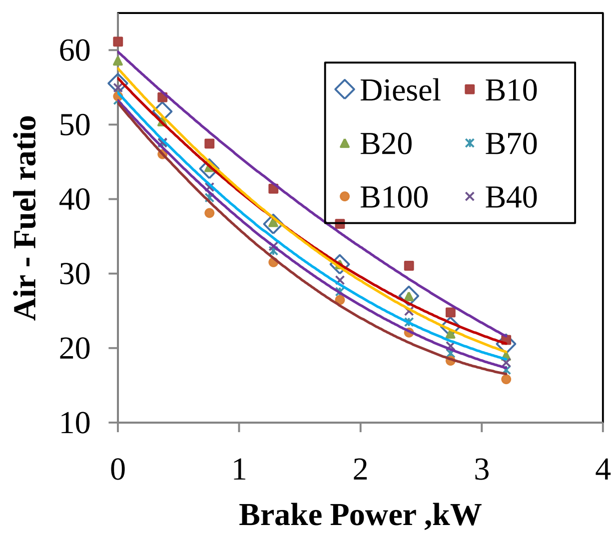

Fig.3. Variation of air – fuel ratio with brake power

D. Exhaust gas temperature

The variation of exhaust gas temperature with respect to brake power for diesel and various biodiesel blends are shown fig 4. The biodiesel also contains some amount of oxygen molecules in the ester form. It is also taking part in the combustion. Up to B10 the exhaust gas temperature is lower than the diesel. This reveals that the effective combustion is taking place in the early stages of exhaust stroke and there is saving with respect to exhaust gas energy loss. This fact is reflected in brake thermal efficiency and brake specific fuel consumption as well. When the biodiesel concentration increases exhaust gas temperature also increases, B100 gives the maximum exhaust gas temperature compared the all blends. It reveals combustion process taking place at the diffusion stage, which is the reason to have lower brake thermal efficiency for higher biodiesel blends.

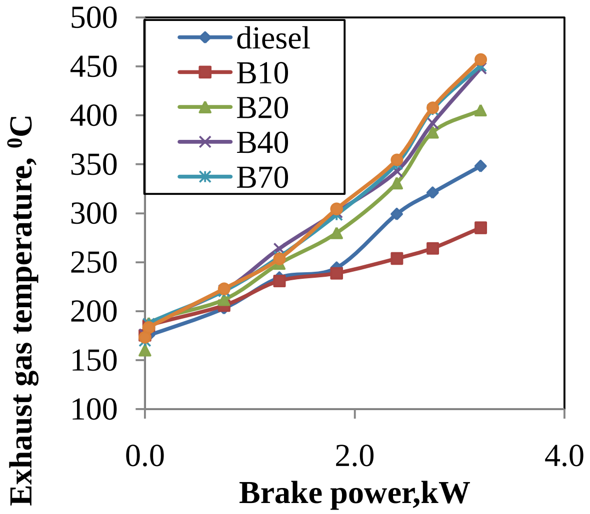

Fig.4. Variation of exhaust gas temperature with brake power

E. Nitrogen oxides

The variation of nitrogen oxides (NO_x) with respect to brake power for diesel and various biodiesel blends are shown in fig 5. The very general reason for increased NO_x emissions for the biodiesel is the increased bulk modulus of compressibility of biodiesel which causes an advance in injection timing and hence a longer ignition delay. The factors which affect the maximum combustion zone location cause an increase in NO_x formation .Also being an oxygenated fuel, biodiesel blends emits higher NO_x as compared to the diesel except B10. The nitrogen oxides emission is directly related to the engine combustion chamber temperatures, which in turn indicated by the prevailing exhaust gas temperature. With increase in the value of exhaust gas temperature, NO_x emission also increases. That is, biodiesel fueled engines has the potential to emit more NO_x as compared to that of diesel fueled engines.

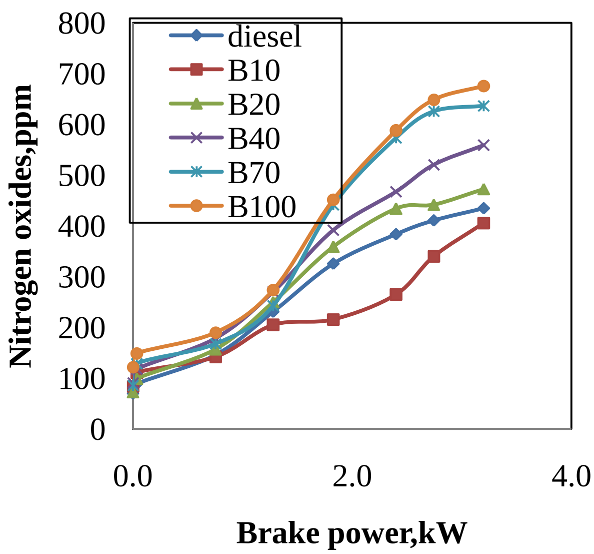

Fig.5. Variation of Nitrogen oxide emissions with brake power

F. Carbon monoxide

The variation of carbon monoxide (CO) emissions with respect to brake power for diesel and various biodiesel blends are shown in fig 6. All fuels are producing low amount of carbon monoxide emission at lighter load levels and are giving more emissions at higher loading conditions due to lower air fuel ratio,incompleate combustion etc. This is typical with all internal combustion engines since the air–fuel ratio decreases with increase in load. B10 gives the lower CO emissions compared diesel and other biodiesel blends at the rated load, because B10 is having higher air fuel ratio as compared to diesel and other biodiesel blends.B100 emits the very high CO emissions.

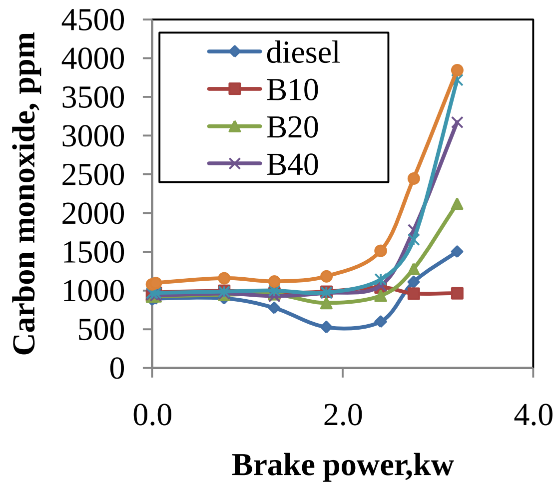

Fig.6.Variation of carbon monoxide emissions with brake power

G. Hydrocarbons

The variation of hydrocarbon emissions with respect to brake power for diesel and various biodiesel blends are shown in fig 7. The hydrocarbons emissions depends on engine's operating conditions, fuel spray characteristics, fuel properties and interaction between fuel and air in the combustion chamber. The hydrocarbon emissions increase with load for all the fuel, mainly due to less availability of excess air leads to incomplete combustion. At the rated load B10 emits the lower HC emissions as compared to diesel and other biodiesel blends due to presence oxygen component helps to have complete combustion. But for higher blends hydro carbon emission are increasing, main reason is that combustion started at diffusion zone, so sufficient time may not available to have the complete combustion.

H. Excess air

The variation of excess air with respect to brake power for diesel and various biodiesel blends are shown in fig.8. For all fuels excess air continuously decreasing with increasing load due to decrease of air fuel ratio.Excees air is decreasing with increasing the biodiesel concentration except B10 because of its higher air fuel ratio. B100 gives the lower excess air as compared to all other blends.

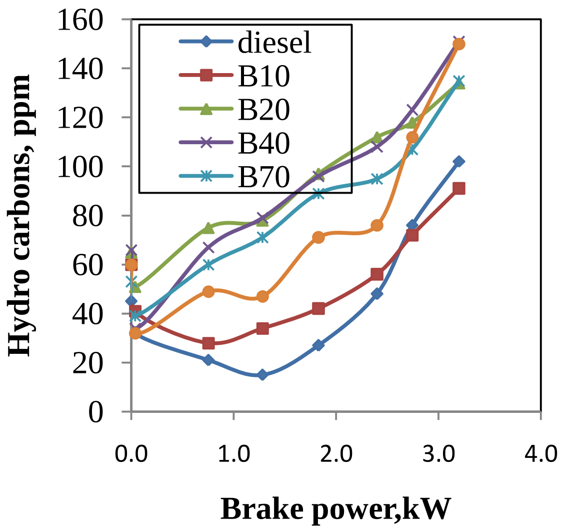

Fig.7.Variation of hydrocarbon emissions with brake power

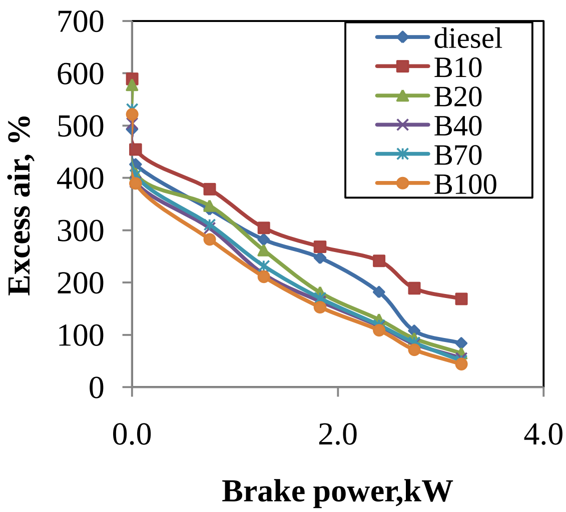

Fig.8.Variation of excess air with brake power

VI. CONCLUSIONS

Biodiesel was developed from waste chicken fat using two step esterification method. All the properties were obtained within the range of ASTM limits of biodiesel. Specific gravity and viscosity is close to the petroleum diesel.caloreific value is lesser than the petroleum diesel. The chemical formula for the biodiesel was obtained from methyl ester profile is $C_{18.2}H_{36.09}O_2$. Chicken fat Biodiesel contains 76.23% of Carbon, 12.59% of Hydrogen and 11.17% of Oxygen. The presence of oxygen molecules in the biodiesel helps to have complete combustion.

Performance and emission test was conducted in compression ignition engine with biodiesel blends and compared with petroleum diesel fuel. At the rated load B10 blend is giving higher brake thermal efficiency by 4.13% and lower specific fuel consumption by 2.66% as compared to petroleum diesel fuel due to complete combustion with presence of free molecules of oxygen content in the chicken fat biodiesel. All exhaust emissions were found lower for B10 blend as compared to petroleum diesel.

The results from this investigation shows that the chicken fat biodiesel can be used in compression ignition engines without any modifications. Among the all tested blends, B10 is giving best performance and emission characteristics.

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