Experimental analysis of performance and emission characteristics of ci engine using hemp oil blended with diesel

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Abstract— *The interest on alternative fuels is continuously increasing to meet the growing energy needs and protect the environment. A successful alternative fuel fulfills the environmental and energy security needs without sacrificing operating performance. One of the successful alternative fuels is biodiesel which is gaining attention in the present day world. Operationally, biodiesel blends perform very similar to conventional diesel in terms of performance and emissions without major modifications of engine because the properties of biodiesel and conventional diesel are similar. biodiesel is prepared from hemp oil and tests were conducted with different blends of biodiesel and diesel on a single cylinder four stroke diesel engine and performance and emissions are evaluated and compared with diesel operation.*

Keywords—Alternate fuel; Biodiesel; Glycerin; Transesterification;

1. Introduction

As the global debate over reducing the dependence on fossil fuel heats up, discussion of alternative fuels is more and more prevalent. One of the most commonly mentioned is biodiesel; a 100% agriculturally derived liquid fuel, often called B100. Most often used as fuel in diesel vehicle engines, biodiesel can also Biodiesel from Sesame Oil be used as heating oil. Biodiesel is made from virgin vegetable oils, from waste frying oils or from waste animal fats and oils. It can be used alone or blended with petroleum diesel in any percentage without major modifications to the engine.

The feedstock for biodiesel production can vary from country to country depending on the availability of certain types of vegetable oil. For example the vegetable oils such as soybean oil in USA, rapeseed oil in Europe, palm oil in Malaysia and Jatropha in India are being used for the production of biodiesel to fuel their compression ignition engines.

Transport sector of Bangladesh mainly use petrol, diesel and compressed natural gas (CNG). There are estimates that the resources for Natural Gas are being depleted and in fact, could hit rock bottom by the year 2020. Presently Bangladesh imports 2.4 million metric ton diesel fuel each year.

The entire amount is imported from Kuwait, Saudi Arabia, the United Arab Emirates and India costing over $2 billion. Demand for diesel surged by around 15 per cent in recent months due to its increased use in captive generators in industries, commercial establishments and apartments as the country has been hit by power shortfall. Higher consumption of diesel, which accounts for approximately 60 percent of total import of petroleum products, will create a fresh pressure on the country's fuel import bill this fiscal. Diesel is also used in the irrigation pumps and in the transportation sector. To meet the increasing demand of diesel, biodiesel may be an alternative source. The production of the oil seeds such as mustard, groundnut, linseed, castor, coconut and hemp oil is ~384115 MTons/year. Biodiesel is commonly produced by the transesterification of the vegetable oil or animal fat feed stock. Though there are several processes for transesterification, batch reaction process is adopted due to the simplicity and adoptability in the laboratory. The percentage of free fatty acids present in the sample of the fuel is estimated by titration process, and the amount of KOH and Methanol is calculated. Following are the sequence of processes in the preparation of biodiesel.

Step 1: Estimation of free fatty acid.

Step 2: Calculation of mass of KOH required for the solution.

Step 3: Calculation of mass of methanol required for the reaction.

Step 4: Calculation of volume of methanol required per liter of sesame oil.

Step 5: Calculation of weight of KOH required per liter of sesame oil.

Step 6: Preparation of biodiesel. incorporating the applicable criteria that follow.

Renewable fuels like bio diesel are becoming increasingly popular alternatives to petroleum based fuels. While vegetable oil can be burned directly, it is not recommended as an engine fuel due to its high viscosity. In the transesterification reaction, vegetable oil, that is predominately made up of triglyceride molecules, is re- acted with an alcohol (usually methanol) to produce a by-product, glycerol, and three bio diesel molecules with viscosity and other properties similar to those of petroleum diesel fuel. The recent increase in biodiesel production has also led to increasing interest in developing new uses for the low-cost glycerol by-product (Acosta etal., 2011).

2. Materials And Methods

A. Chemicals

Methanol (99-100%), ethanol (99-100%), sodium hydroxide pellets (96%), potassium hydroxide pellets (>84%), phenolphthalein (pH 8.2 - 9.8), starch, acetone (99%), benzene, sodiumthiosulfate (99.0%), n-Hexane (96%), hydrochloric acid (37%) , sulfuric acid (98%), isopropanol, iodine, sodium iodide, glacial acetic acid, bromine, carbon tetrachloride, phosphoric acid (85%), s-Diphenylcarbazide, Potassium Dichromate etc. were purchased from Merck, Germany. All the chemicals used were analytical reagent grade.

B. Extraction of oil

1.5 liters of hemp oil is taken in a 2 liter beaker and it is heated on a water bath (approximately to 400 C), to get cloudless clear oil. 13.65 gm of KOH is mixed with 324 ml of methanol and stirred until KOH dissolves completely. Mixture of KOH and methanol is added to 1.5 liters of hemp oil at 400C and the contents are transferred in to a 2 liter bottle and shaken rigorously for 10 minutes to ensure proper mixing of oil, alcohol and catalyst. The bottle is kept upside down without any movement for 2-days and it is observed the formation and settlement of glycerin at the bottom and biodiesel at the top. Glycerin is collected carefully and left over biodiesel is washed with water and dried in sun to remove any water present. The yield of biodiesel is found to be 1450 ml.

C. Synthesis of biodiesel by transesterification

Biodiesel from hemp oil was synthesized by base catalyzed transesterification reaction. The reaction was carried out at 60 0C and atmospheric pressure under reflux for 90 minutes with vigorous stirring. Typically 50 gm of oil sample were placed in a two-necked 250 mL round bottom flask equipped with a reflux condenser. The flask was immersed in an oil bath with a temperature controller and magnetic stirrer. Sodium hydroxide pellets (1 wt % of oil) was dissolved in required amount of methanol. Methanol was used 6:1 molar ratio to oil. The sodium-methoxide solution was transferred into the reaction flask. After 90 minutes the reaction was stopped by adding required stoichiometric amount of concentrated hydrochloric acid and then the contents were cooled to room temperature. After the reaction period, the reaction product was allowed to stand 12-14 hour in a separatory funnel. Three separate layers were observed. Upper layer was excess methanol, middle layer was methyl ester (Biodiesel) and lower layer were a mixture of soap, crude glycerin and lye catalyst. The Biodiesel layer was separated and this layer was opaque as it contained some catalyst, methanol, triglyceride and soap. Biodiesel from hemp Oil.

TABLE I. Properties Of Diesel And Hemp Oil And Its Methyl Ester

FUEL PROPERTIES	DIESEL OIL	HEMP OIL
Density (g/cm³)	0.830	0.858
Kinematic Viscosity(cSt)@40°C	3.55	2 5.13
Flash point (°C)	55	47
Fire Point (°C)	65	55
Cloud Point	-12	-4
Calorific Value(KJ/kg)	D. 43000	39081

E. Experimental Set up

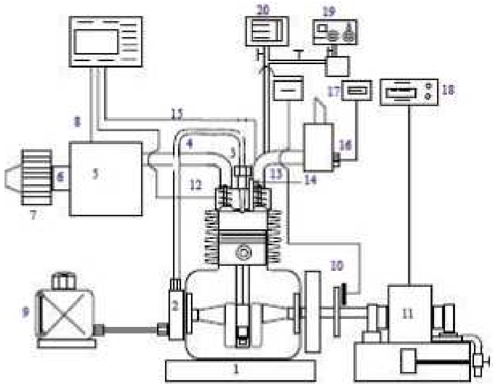

Fig.1 Experimental setup.

1. Engine, 2. Fuel injection pump,3. Fuel injection nozzle
4. Intake manifold ,5. Intake air surge tank ,
6. Air flow meter ,7. Air cleaner,8. Intake air temp sensor
9. Fuel tank, 10. Crank angle detector,
11. Electric dynamometer ,12. Coolant temp sensor
13. Exhaust manifold, 14.Compression pressure transducer
15. Exhaust gas temp sensor, 16. Air-fuel ratio sensor
17. A/F meter , 18. Dynamometer control panel
19. Gas analyzer, 20. Smoke meter.

F. Engine Specification

- The BHP : 5 Hp
- Bore : 80 mm
- Stroke : 110 mm
- Speed : 1500 RPM
- Method of cooling : Water Cooled
- Air Drum Orifice : 20 mm
- Type of ignition : Compression Ignition
- Method of loading : Electric dynamometer.
- Maximum Load : 12.5 Amp

The engine is operated at the rated speed of 1500 rpm for all the tests. For all the tests, the engine is started with diesel fuel and allowed to stabilize for 30 min. After the engine is warmed up, it is then switched to NOME diesel blends. For each experiment, three measurements are taken to average the data so as to determine the repeatability of the measured data and have an estimate of measured accuracy. At the end of test, the fuel is switched back to diesel and the engine is kept running for a while before shutdown to flush out the NOME diesel blends from the fuel lines and injection system. The performance parameter such as Brake Thermal Efficiency (BTE) and brake Specific Energy Consumption (BSFC), combustion parameters such as cylinder pressure, rate of heat release and emission parameters such as like smoke intensity, HC, CO and NO emissions are measured for diesel fuel and NOME diesel blends. Finally, the test results are analyzed and compared with the diesel fuel.

3.RESULTS AND DISCUSSION

G. Trasesterification of hemp oil

1) Effect of oil/ methanol molar ratio

The oil to alcohol molar ratio is one of the important factors affecting the conversion of transesterification reaction of hemp oil to biodiesel. Methanolysis of hemp oil was carried out with catalyst concentration 1.0 wt% of oil at 60 °C and vigorous stirring with different oil/ methanol molar ratio e.g. 1:4.5, 1:6, 1:9 and 1:12 and the results are given in Fig. 2.

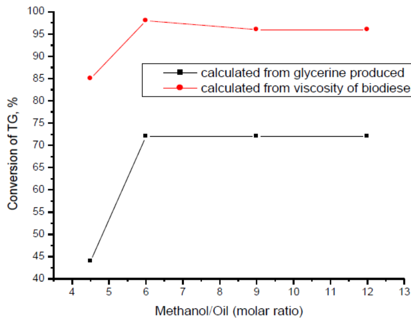

Fig. 2: conversion of hemp oil to biodiesel at different oil/ methanol molar ratio [Reaction temp. 60 □C, Catalyst concentration 1 wt % of oil and Reaction time 90 min under reflux with vigorous stirring].

From Fig.2, it shows that the maximum conversion of hemp oil to biodiesel was found for oil /methanol molar ratio of 1:6 after 90 minutes and the conversion was 98.0% in terms of kinematic viscosity and 72% in terms of glycerin concentration. For both measurement methods, the conversion trends are same for same oil methanol molar ratio. In case of molar ratio 1: 4.5 the reaction time was not sufficient to accomplish the desired conversion. However, the high molar ratio of alcohol to sesame oil interferes with the separation of glycerin because there is an increase in solubility. When glycerin remains in solution, it helps drive the equilibrium to back to the left lowering the yield of biodiesel.

2) Effect of catalyst concentration on transesterification

The conversion of sesame oil to biodiesel is greatly affected by catalyst concentration. Biodiesel conversion was measured by both measuring the concentration of glycerin produced in reaction and the kinematic viscosity of the produced biodiesel. Methanolysis of sesame oil was carried out with NaOH as a catalyst at concentration range from 0.25 − 1.5 wt% of oil at 60 °C with oil/methanol molar ratio of 1: 6. The results are given in Fig. 3

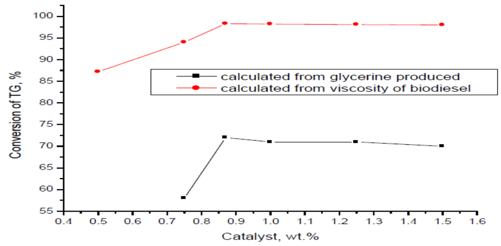

Fig. 3: conversion of sesame oil to biodiesel at different catalyst concentration [Reaction temp. 60 □C, oil / methanol molar ratio 1:6 and Reaction time 90 min under reflux with vigorous stirring].

From the Fig. 3, it shows that the lower catalyst concentration i.e. 0.25 wt% NaOH of oil was insignificant to catalyze when the conversion of sesame oil to biodiesel was measured in terms of glycerin concentration and conversion was 87.2% from oil to biodiesel when measured in terms of kinematic viscosity. However 0.87 wt% NaOH of oil was optimal in the reaction both measurement with a conversion of 72% in terms of produced glycerin concentration and with a conversion of 98.3% in terms of kinematic viscosity in just 90 minutes. With the increase in concentration of catalyst, there was decrease in the yield of methyl ester. This was in accordance with the result obtained by Dorado et al. (2004). and was due to the formation of soap in presence of high amount of catalysts, which increased the viscosity of the reactants and lowered the conversion. Conversion of triglyceride found by glycerin determination method was lower than that of determined by viscosity method. The lower conversion from the result was expected as considerable amount of glycerin was lost during the separation of glycerin layer and some of the glycerin remained in the biodiesel layer.

3) Effect of catalyst concentration on transesterification

Properties of the produced biodiesel and comparison with biodiesel and petro-dieselstandard are given in Table 2.

The quality of biodiesel was determined by measuring some property such as cetane number which indicates ignition characteristic. Cetane number of biodiesel was slightly lower but higher than standard value of biodiesel. But the cetane number of the blend of sesame oil with petro diesel was higher than standard value of biodiesel. Flash point of the produced biodiesel was higher than petro-diesel which is safe for transport purpose[1].Other properties such as kinematic viscosity, cloudpoint, pour point, density, pH, saponification value etc. were measured.

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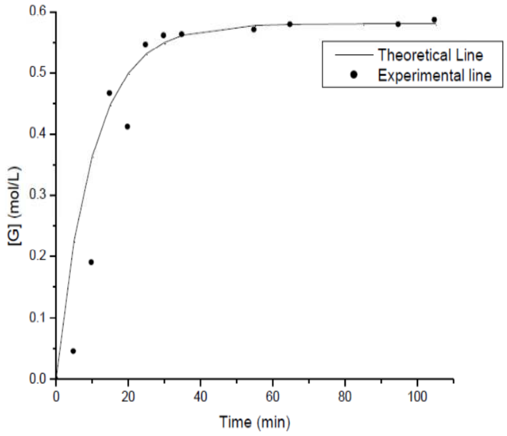

4.CONCLUSION

Biodiesel has been synthesized from hemp oil by base catalyzed transesterification reaction. Raw hemp oil has 6.1% FFA content. The properties of the raw oil were investigated. The optimum condition for the base catalyst transesterification reaction was determined. The optimum condition for the base catalyst transesterification reaction was 0.85 wt% NaOH to oil as catalyst, methanol/oil molar ratio of 6:1 and the maximum conversion was 98.56% from oil to biodiesel at 90 minutes.A significant reduction of viscosity and acid value was found. The properties, such as specific gravity, viscosity, flash point, cloud point, pour point and calorific value are comparable with the standard value of biodiesel and petro-diesel. The present experimental results support that biodiesel from hemp seed oil can be successfully used as diesel.

REFERENCE

[1] Ando B, Baglio S, Graziani S and Pitrone N (2000) Models for air quality management and assessment. IEEE Trans. on systems, man and cybernetics-part c: applications and reviews. 30(3), 358-363.

[2] Allen, C.A.W.; Watts, K.C.; Ackman, R.G.; Pegg, M.J. Predicting the viscosity of biodiesel fuels from their fatty acid ester composition. Fuel 1999, 78, 1319–1326.

[3] Bajpai,D.; Tyagi, V.K. Biodiesel: Source, production, composition, properties and its benefits. J. Oleo Sci. 2006, 55, 487–502.

[4] C.J. Arrowsmith, J. Ross, Treating fatty materials, U.S. Patent No. 2,383,580 (1945).

[5] Chapman L (2007) Transport and climate change: a review. J. of Transport Geography. 15, 354–367.

[6] Demirbas, A. Relationships derived from physical properties of vegetable oil and biodiesel fuels. Fuel 2008, 87, 1743–1748.

[7] Divya Bajpai., Tyagi.V.K. (2006) Biodiesel: source, production composition, properties and its benefits.Jounal of oleo science, 55(10): 487-502.

[8] Duncan RC and Youngquist W (1999) Encircling the peak of world oil production. Natural Res. Res. 8, 219–232.

[9] El-Diwani, G.; Attia, N.K.; Hawash, S.I. Development and evaluation of biodiesel fuel and by-products from jatropha oil. Int. J. Environ. Sci. Technol. 2009, 6, 219–224.

[10] [10] G.B. Bradshaw, New soap process, Soap, 18, May (1942) 23–24, 69–70.

[11] G.B. Bradshaw, W.C. Meuly, Process of making pure soaps. U.S. Patent No. 2,271,619 (1942).

[12] G.B. Bradshaw, W.C. Meuly, Preparation of detergents, U.S. Patent No. 2,360,844 (1944).

[13] Gattamaneni LNR, Subramani S, Santhanam S and Kuderu R (2008) Combustion and emission characteristics of diesel engine fuelled with rice bran oil methyl ester and its diesel blends. Therm. Sci. 12(1), 139-150.

[14] Ghobadian B, Rahimi H, Nikbakht AM, Najafi G and Yusaf TF (2009) Diesel engine performance and exhaust emission analysis using waste cooking biodiesel fuel with an artificial neural network. Renew. Energy. 34, 976–982.

[15] G.G. Pearl, Animal fat potential for bioenergy use, Bioenergy 2002, The Tenth Biennial Bioenergy Conference, Boise, ID, Sept. 22–26, 2002.

[16] GuoqingGuan, Katsuki Kusakabe, Nozomi Sakurai, Kimiko Moriyama. (2009) Transesterification of vegetable oil to biodiesel fuel using acid catalysts in the presence of dimethyl ether. Fuel, 88: 81-86.

[17] H.D. Allen, W.A. Kline, Process for treating fats and fatty oils, U.S. Patent No. 2,383,579 (1945).

[18] Imahara, H.; Minami, E.; Saka, S. Thermodynamic study on cloud point of biodiesel with its fatty acid composition. Fuel 2006, 85, 1666–1670.

[19] J.H. Percy, Treatment of fatty glycerides, U.S. Patent No. 2,383,614 (1945).

[20] J. Sheehan, V. Camobreco, J. Duffield, M. Graboski, and H. Shapouri, Life cycle inventory of biodiesel and petroleum diesel for use in an urban bus, final report for U.S. Dept. of Energy's Office of Fuel Development and the U.S. Dept. of Agriculture's Office of Energy, by the National Renewable Energy Laboratory, NREL/ SR-580-24089 (May 1998).

[21] McCormick, R.L.; Ratcliff, M.; Moens, L.; Lawrence, R. Several factors affecting the stability of biodiesel in standard accelerated tests. Fuel Process. Technol. 2007, 88, 651–657.

[22] Rashid, U.; Anwar, F. Production of biodiesel through base-catalyzed transesterification of safflower oil using an optimized protocol. Energy Fuels 2008,

[23] Rashid, U.; Anwar, F.; Moser, B.R.; Ashraf, S. Production of sunflower oil methyl esters by optimized alkali-catalyzed methanolysis. Biomass Bioenergy 2008, 32, 1202–1205.

[24] Rashid, U.; Anwar, F.; Ansari, T.M.; Arif, M.; Ahmad, M. Optimization of alkaline transesterification of rice bran oil for biodiesel production using response surface methodology. J. Chem. Technol. Biotechnol. 2009, 84, 1364–1370.