International Journal of Current Engineering and Technology
ISSN 2277 - 4106
© 2013 INPRESSCO. All Rights Reserved.
Available at http://inpressco.com/category/ijcet

Research Article

Experimental Investigation on Engine Performance of Diesel Engine Operating on Peanut Seed Oil Biodiesel Blends

Hanchate Suresh Babu Rao[a*], B. Venkatesh[a], Dr. T. Venkateswara Rao[b], K. Hema Chandra Reddy[c]

[a]Department of Mechanical Engineering, J.N.T. University Anantapur, A.I.T.S-Rajampet, India
[b]Department of Mechanical Engineering, J.N.T. University Anantapur, DBSIT-Kavali, India
[c]Department of Mechanical Engineering, J.N.T. University Anantapur, J.N.T.U.C.E-Anantapur, India

Accepted 10 October 2013, Available online 21 October 2013, **Vol.3, No.4 (October 2013)**

Abstract

The world is confronted with serious problems like fossil fuel depletion and environmental degradation. Fossil fuels in near future will become rare due to its indiscriminate extraction and consumption. Therefore, biodiesel is considered as a promising option as they are clean renewable fuels and best substitute for diesel fuel in any compression ignition engine. The important advantages of using biodiesel are its renewability and better quality of exhaust gas emissions. In this research, biodiesel was synthesized from peanut seed oil via base catalyzed transesterification using NaOH as the catalyst. The synthesized fatty acid methyl ester after being washed was blended with diesel in the following percentage by volume of the biodiesel 0%, 20%, 40%, 60%, 80% and 100% corresponding to B0, B20, B40, B60, B80 and B100 respectively. Thus the prepared biodiesel blends and tested on a diesel engine. The properties of fuel are found such as viscosity, flash point, fire point and calorific value. Also, the investigation of engine performances on diesel like brake power, brake specific fuel consumption, brake thermal efficiency, indicated thermal efficiency and exhaust gas temperature of various blends of peanut seed oil was carried out and their comparison made. Finally, a discussion on emissions is also given in this paper.

Keywords: *biodiesel, peanut oil, transesterification, engine performance, emission.*

1. Introduction

The rising demand for fuel with deterioration of climate conditions has raised concerns for environmental problems and energy crisis. Biodiesel is the promising option as alternative fuels for diesel engine (edible or non-edible feedstock). Biodiesel is defined as the mono-alkyl esters with long chain of fatty acids derived from vegetable oils, animal fats or waste cooking oil. Biodiesels are renewable, nontoxic, non-flammable, readily available and also eco-friendly. Biodiesel have some advantages as compared to petroleum diesel. The most important advantages of biodiesel are biodegradability, higher flash point, improved cetane number and reduced exhaust emissions. Also, biodiesels are free from sulfur or aromatic compounds and reduces air pollution like carbon monoxides, hydrocarbons and particulate matter. Therefore, this makes biodiesel as an ideal fuel for future and it is gaining a worldwide attention.

The important advantages of using the Biodiesel are its renewability, better quality exhaust gas emission, biodegradability; it does not contribute to a rise in the level of carbon dioxide in the atmosphere. The main commodity sources for biodiesel (both edible and non-edible oils) can be obtained from such as edible oils like Peanut oil, Sunflower oil, Soyabeen oil etc

Biodiesel seems to be a realistic alternative renewable fuel in the near future and this paper focuses on the possibilities of using peanut seed oil as biodiesel in a diesel engine. Besides, the fuel characteristics, processes available, production, performance and exhaust analysis of biodiesel are discussed by making a comparison on these types of biodiesel fuels

2. Biodiesel

The concept of using biodiesels in diesel engines is not a new idea, Rudolph Diesel demonstrated his first developed compression ignition (CI) diesel engine using peanut oil as a fuel at the World Exhibition at Paris in 1900. However due to abundant supply of diesel and vegetable oil fuels were more expensive than diesel in those days and the research activity and developments on vegetable oil were not seriously taken. There is a renewed interest in vegetable oil in this decade when it was conclusively realized as petroleum fuels are declining faster and need of environmental friendly renewable substitutes must be found. Therefore, the area of research on biodiesel is gaining more and more interest as an attractive fuel due to

*Corresponding author: **Hanchate Suresh Babu Rao**

the depleting fossil fuel resources and environmental degradation.

Biodiesel which has combustion characteristics similar to diesel and biodiesel blends has higher ignition temperature and pressure, shorter ignition delay as well as peak heat release when compared to diesel fuel. Moreover, the engine power output and brake power efficiency was found to be equivalent to diesel fuel. Biodiesel and diesel blends can reduce smoke opacity, particulate matters, un-burnt hydrocarbons, carbon monoxide and carbon dioxide emissions but nitrous monoxide emissions have slightly increased. However, the main disadvantages of biodiesel is their high viscosity and low volatility, which causes poor combustion in diesel engines including formation of deposits and injector cocking due to poorer atomization upon injection into the combustion chamber. By transesterification, of the oil reduces its viscosity and the viscosity of oil will be to a range closer to that of diesel and hence improves combustion. Biodiesels or fatty acid esters are clean, efficient and natural alternative to petroleum fuels. The use of biodiesel has grown dramatically during the last few years. Feedstock costs account for a large portion of the direct biodiesel production costs, including capital cost and return.

2.1 Standards of biodiesel

In general terms, biodiesel may be defined as a domestically renewable fuel for diesel engines derived from natural oil like peanut, sunflower, rapeseed etc., and the oil that meet the specifications of testing. Technical properties of biodiesel are given in Table 1. Biodiesel is a clear amber-yellow liquid with a viscosity is similar to diesel fuel.

Table 1 Technical Properties of Biodiesel

S.No	Common Name	Biodiesel
1	Common chemical name	Fatty acid methylester
2	Chemical formula range	C14 - C24 methylesters or C15 - 25 H28-48 O2
3	Kinematic viscosity range (mm ^{2}/s)	3.3 - 5.2
4	Density range (kg/m^3 , at 288K)	860 - 894
5	Boiling point range (K)	>475
6	Flash Point range	420-450
9	Solubility in water	insoluble
10	Physical appearance	Light to dark yellow, clear liquid

2.2 Biodiesel Feedstock sources

Fig. 1 shows the oil yields of various oil sources for biodiesel feedstock. Peanut oil productivity is larger compared sunflower, cotton seed oil and soybean oils. The seed contains 50% oil that may provide an inexpensive source of triglycerides for conversion to biodiesel.

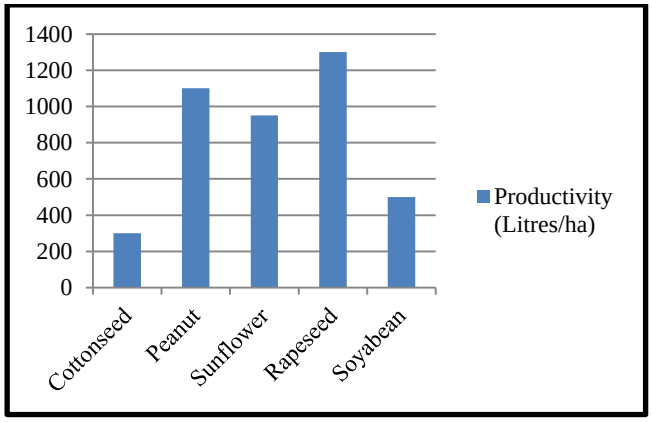

Fig. 1. Production oil yield for various source of biodiesel feedstock

3. Peanut / Groundnut Seeds

Scientific name of peanut or groundnut is Arachis hypogaea. Peanut/groundnut is an important crop grown in world-wide. Peanut is currently grown on over 22.2 million hectares worldwide with a total production of over 35 million tones.

Fig. 2 Peanut / Groundnut seeds

India and China are the world's largest producers of peanuts, accounting for over 41% and over 18% of world production respectively. Even as India and China are the world's largest producers (Fig. 3), they account for only a small part of international trade because most of their production is consumed domestically as peanut oil. Exports from India and China are equivalent to less than 4% of world trade. 90% of India's production is processed into peanut oil. Only a nominal amount of hand-picked select-grade peanuts are exported. The major exporters are the United States, Argentina, Sudan, Senegal, and Brazil. These five countries account for 71% of total world exports, with the United States being the leading exporter. The major peanut importers are the European Union, Canada, and Japan. These three areas account for 78% of the world's imports.

Peanuts can be eaten as raw or as peanut butter, used in recipes and made into solvents and oils which are in turn used in medicines, textile materials, cosmetics, nitro-

glycerine, plastics, dyes, paints, varnishes, lubricating oils, leather dressings, furniture polish, insecticides, and soap. Peanut shells are used in the manufacture of plastic, wallboard, abrasives, fuel, cellulose and glue. Peanut is a high protein content, and is a good flavour enhancer.

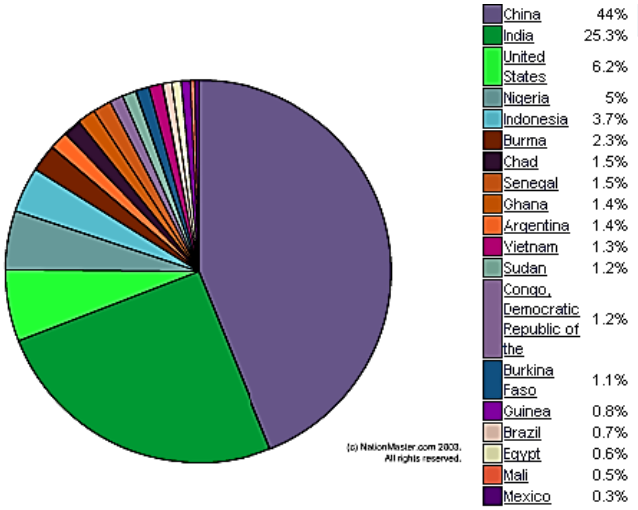

Fig. 3 World Peanut Production for year 2012

Peanut provides over 30 essential nutrients and phytonutrients, including niacin, folate, fibre, magnesium, vitamin E, manganese and phosphorus. Peanut-based pastes high in protein, calories and other nutrients, have been developed for use by relief organisations as a therapeutic food in emergency situations of extreme drought and famine, particularly targeting malnourished children.

3.1 Peanuts cultivation by intercropping method

Peanuts crop cultivation by Intercropping is very important. when Intercropping with two or more crops with different rooting systems, a different pattern of water and nutrient demand, and a different ground habit and planted together, water, nutrients and sunlight are used more efficiently Fig.4. Therefore, the combined yields or two crops grown as intercrops can be higher than the yield of the same crops grown as pure stand. An important reason for intercropping is the improvement and maintenance of soil fertility.

Fig. 4 Peanut in intercropping

Nitrogen fixation due to peanut cropping increases soil fertility. And if the right bacteria's are present in the soil, pulse crops can fix nitrogen gas from the air in pores in the soil, thereby reducing the need for nitrogen form manure or fertilizers. ICRISAT studies have shown that the there is good evidence that peanut and cereal intercropping can give worthwhile yield advantages over sole cropping.

Rice and peanut intercropping resulted in a high rice grain yield, and this was mainly attributed to the improvement in Nitrogen nutrition supplied by the intercropped peanut. The BNF (Biological Nitrogen Fixation) by peanut was increased by growing the crop with rice but was decreased at increasing Nitrogen fertilizer application rates. The Nitrogen transferred from peanut made a significant contribution to the Nitrogen nutrition of rice, especially in low-Nitrogen soil. The results obtained in experiments proved that the new intercropping system is very promising for the development of sustainable food production within the limited natural resources countries like China and India.

Hence, productivity of peanut crop can increase by growing it through intercropping in rice and cereals crops and also, productivity of both the intercropping crops can increase. This leads to more supply of peanut in worldwide and is a suitable for option as biodiesel.

4. Production of Biodiesel

4.1 Simple transesterification reaction

Transesterification of vegetable oils with simple alcohol has long been the preferred method for producing biodiesel. In general, there are two methods of transesterification. One method simply uses a catalyst and the other is without a catalyst.

4.2. Chemistry of transesterification reaction

The overall chemical reaction of the transesterification process is:

$$\begin{array}{l} CH_2\text{-}OOC-R_1 \\ | \\ CH_2\text{-}OOC-R_2 \\ | \\ CH_2\text{-}OOC-R_2 \end{array} + 3R'OH \xrightleftharpoons{\text{Catalyst}} \begin{array}{l} R_1\text{-}COO\text{-}R' \\ | \\ R_2\text{-}COO\text{-}R' \\ | \\ R_3\text{-}COO\text{-}R' \end{array} + \begin{array}{l} CH_2\text{-}OH \\ | \\ CH\text{-}OH \\ | \\ CH_2\text{-}OH \end{array}$$

Glyceride Alcohol Ester Glycerol

Fig. 5 Transesterification reaction of triglycerides with alcohol

Transesterification (also called alcoholysis) is the reaction of a fat or oil with an alcohol to form esters and glycerol. The reaction is shown in Fig. 5. A catalyst is usually used to improve the reaction rate and yield. Because the reaction is reversible, excess alcohol is used to shift the equilibrium to the products side.

Alcohols are primary and secondary monohydric aliphatic alcohols having 1±8 carbon atoms. Among the

alcohols that can be used in the transesterification process are methanol, ethanol, propanol, butanol and amyl alcohol. Methanol and ethanol are used mostfrequently, especially methanol because of its low cost and its physical and chemical advantages (polar and shortest chain alcohol). It can quickly react with triglycerides and NaOH is easily dissolved in it. To complete a transesterification stoichiometrically, a 3:1 molar ratio of alcohol to triglycerides is needed.

In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield. The reaction can be catalyzed by alkalis, acids, or enzymes. The alkalis include NaOH, KOH, carbonates and corresponding sodium and potassium alkoxides such as sodium methoxide, sodium ethoxide, sodium propoxide and sodium butoxide. Sulfuric acid, sulfonic acids and hydrochloric acid are usually used as acid catalysts. Lipases also can be used as biocatalysts. Alkali-catalyzed transesterification is much faster than acid-catalyzed transesterification and is most often used commercially.

For an alkali-catalyzed transesterification, the glycerides and alcohol must be substantially anhydrous because water makes the reaction partially change to saponification, which produces soap. The soap lowers the yield of esters and renders the separation of ester and glycerol and the water washing difficult. Low free fatty acid content in triglycerides is required for alkali-catalyzed transesterification. If more water and free fatty acids are in the triglycerides, acid catalyzed transesterification can be used. The triglycerides can be purified by saponification (known as alkali treating) and then transesterified using an alkali catalyst.

4.3 Peanut biodiesel preparation

Firstly, the peanut seed oil (refined) purchase from the local market and for further transesterification process takes place by following steps:

1) Biodiesel derived from peanut seed oil was prepared by reacting 300 g of oil, 60 g CH3OH (approximately 6:1 molar ratio) and 1.5 g NaOH. The reaction was carried out for one hour under reflux at 60^0C while stirring [fig.6].
2) The mixture is now allowed to settle for one hour in a separating funnel at which two separate layers are obtained. Top layer is required is separated and the bottom layer glycerin, which is removed out.
3) Later, the top layer of the oil is taken in round bottom flask and heated to 65 to 80^0C. The methanol vaporizes and it is collected at the other end of condenser [fig.7].
4) The oil is collected in a separating funnel and allowed to settle for 8 hours. Again, two layers are formed, the top layer is required methyl ester is separated and bottom layer is glycerin, which is removed out.
5) Since the remaining unreacted methanol & NaOH in the methyl ester has safety risks and can corrode engine components. Thus the obtained methyl esters is washed (3 – 4 times) with warm water at 55 – 65^0C [Fig.8].
6) Finally, the methyl ester is heated to 1100C to evaporator the water present in it. Thus obtained methyl ester is collected for further tests. And such formed biodiesel is blended with diesel in blends like B0, B20, B40, B60, B80 and B100.

Fig. 6. Stirring

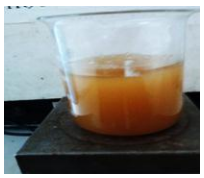

Fig. 7. Heating

Fig. 8. Water washing

Table 2 Properties of Peanut oil and its methylester.

S.No.	Property	Crude Peanut oil	Peanut oil Methyl ester
1	Density (kg/m^3)	956	922
2	Specific gravity	1.1	0.96
3	Cloud Point (^{o}C)	8	11
4	Pour Point (^{o}C)	-3	-6
5	Flash Point (^{o}C)	455	180
6	Heating Value (MJ/kg)	39.1	39.52
7	Cetane number	24	48
8	Kinematic viscosity (mm^2/sec)	243.25	6.2

5. Experimental Setup

Fig.9 shows the experimental setup of a single cylinder with water-cooling system, Mechanical dynamometer, four stroke; type - direct injection (DI) diesel engine (specification Table 3) was used for performance testing.

Fig. 9. Single Cylinder Four Stroke Diesel engine test rig

Table 3 Engine Specification

Make	Kirloskar
Bore & Stroke	80mm & 110mm
Compression ratio	16.5 : 1
Rated power	3.7 kW at 1500 rpm
Number of cylinder	0ne
Number of stroke	Four
Cooling type	Water
Type of Dynamometer	Mechanical

6. Results & Discussion

6.1 Performance Parameters

The experimental investigation was carried out for different blends of peanut methyl ester, the performance is evaluated for all the blends and compared with diesel.
From the Fig. 10 it is observed that the kinematic viscosity of different blends of peanut methyl ester B0, B20, B40, B60, B80, and B100. Out of these blends B20 and B40 are very close to kinematic viscosity of diesel.

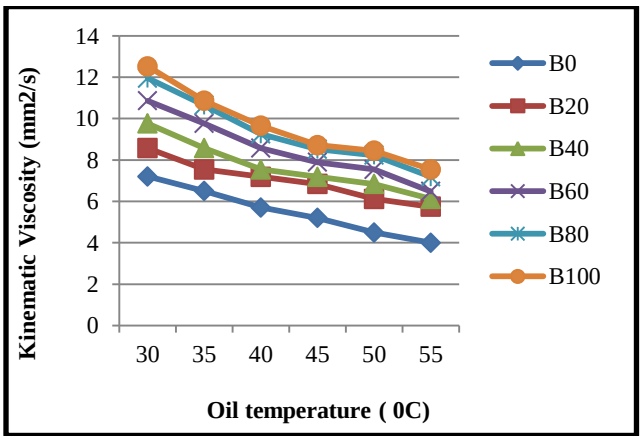

Fig.10. Variations of Kinematic Viscosity with Oil temperature.

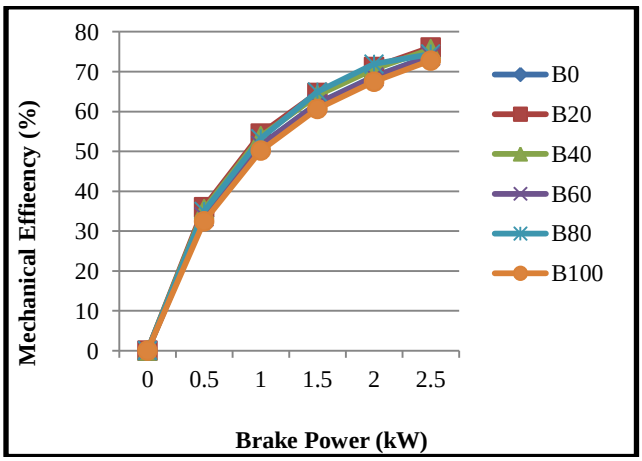

Fig.11. Variations of Brake thermal efficiency with BP

From the Fig.11 it is observed that the mechanical efficiency is high for B20 and B40 blends of peanut biodiesel and the mechanical efficiency of diesel is equal to the brake thermal efficiency of B60 at different loading conditions. So B20 and B40 can be suggested as best of the biodiesel.

From the Fig.12 it is observed that the brake thermal efficiency is high for B20 blend of peanut biodiesel and the brake thermal efficiency of diesel is equal to the brake thermal efficiency of B80 at different loading conditions. So B20 can be suggested as best of the biodiesel.

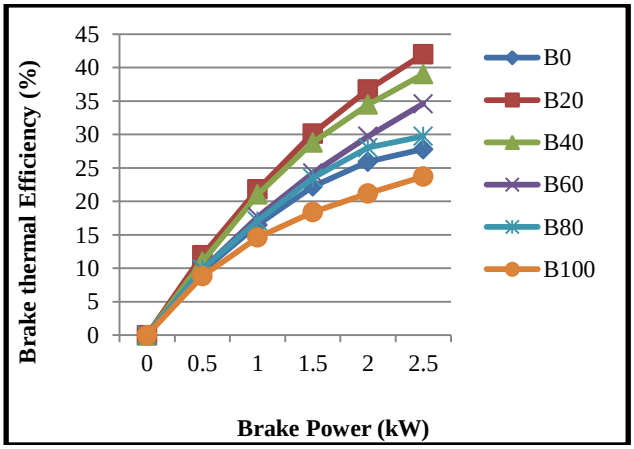

Fig.12. Variations of Brake thermal efficiency with BP

From the Fig.13 it is observed that the indicated thermal efficiency is high for B20 of peanut biodiesel and the indicated thermal efficiency of diesel is equal to the indicated thermal efficiency of B80 at different loading conditions.

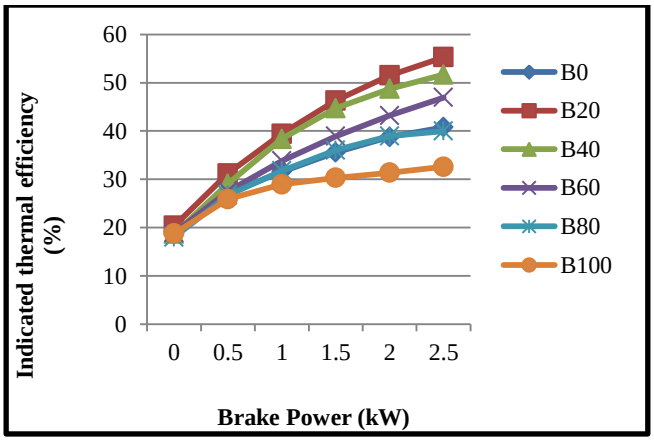

Fig.13. Variations of indicated thermal efficiency with BP

From the Fig.14 it is observed that fuel consumption is low for B20 and B40 blends as compared to diesel. The fuel consumption of B80 is almost equal to the diesel.

From the Fig.15 it is observed that there is less variation in the specific fuel consumption of different blends as compared to diesel. The specific fuel consumption of B20 and B40 is less compared to diesel, and B80 has specific fuel consumption closer to diesel.

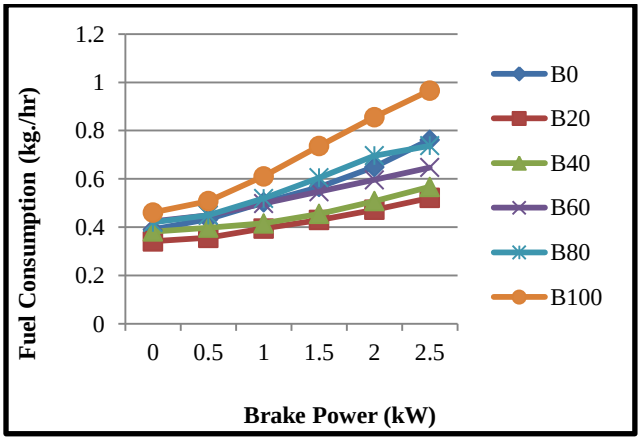

Fig.14. Variations of Fuel Consumption with BP

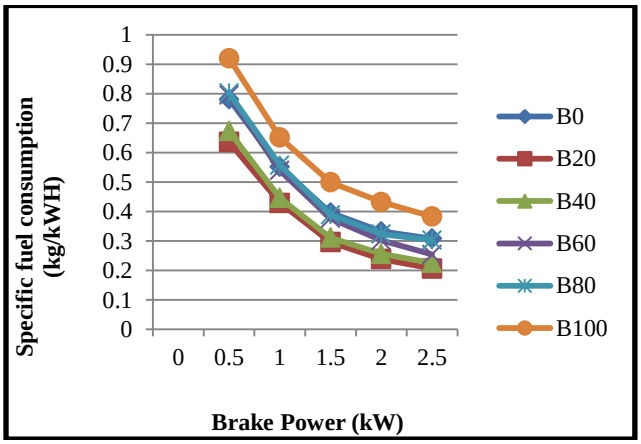

Fig.15. Variations of Specific Fuel consumption with BP

From the Fig.16 it is observed that the exhaust gas temperatures of diesel is high than compared to different blends of biodiesel because of high combustion efficiency of diesel and as biodiesel has lubricating property.

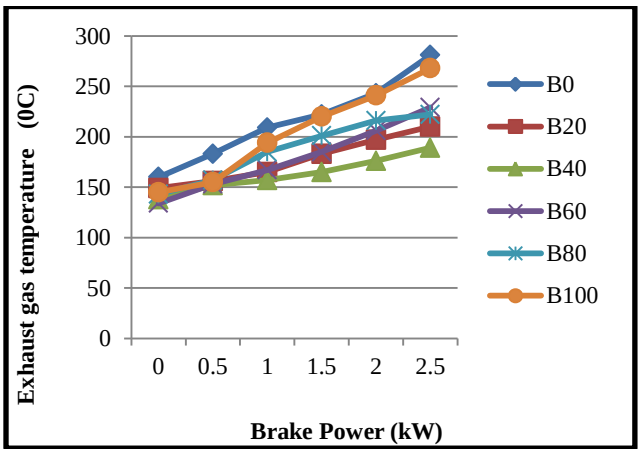

Fig.16. Variations of Exhaust gas temperature with BP.

6.2 Emissions

Peanut methyl ester has about 8% less heating value than that of diesel oil due to the oxygen content in their molecules. Also, the calorific value of peanut biodiesel is found to be slightly lower than that of diesel about 6%.

The biodiesel generally contains about 10 wt. % of oxygen and can be considered it as a kind of oxygenated fuel. The high oxygen content in biodiesel results in the improvement of its burning efficiency, reduction of PM, CO and other gaseous pollutants, but at the same time produces larger NOx formation, particularly under a high temperature burning environment. It is estimated that the burning of neat biodiesel would produce about 10% more NOx than that of petroleum-based diesel, primarily due to the high oxygen content of the neat biodiesel. Nitrogen oxides are the precursors of ozone and acid rain, which are detrimental to the environment as well as the human respiratory system. No_X can be reduced by using Exhaust gas recirculation method and this could be a suitable solution to this problem. Therefore methyl ester of peanut seed oil helps in controlling air pollution to a great extent.

Conclusions

With regard to the experimental study for peanut seed oil as a renewable alternative source of fuel for diesel engines, the following conclusions are drawn:

1) The peanut seed contains 50% oil that may provide an inexpensive source of triglycerides for conversion to biodiesel. The cultivation of peanut can be improved by intercropping.
2) Crude peanut seed oil was transesterified using NaOH as catalyst and methanol to form biodiesel. Biodiesel was obtained at laboratory scale from transesterification of crude peanut seed oil with methanol, using sodium hydroxide as a catalyst, in a batch process. The conversion was taken at 60^0C with 1:6 molar ratio (oil to methanol) for NaOH (0.5%) catalyzed transesterification.
3) Out of different blends of peanut methyl ester with diesel, B20 and B40 showed better performance when compared with other blends i.e., their specific fuel consumption, mechanical efficiency, brake thermal and indicated thermal efficiencies at various loads shows slightly higher than diesel. Also, there is a significant improvement in their burning efficiency, reduction of PM, CO and other gaseous pollutants, but at the same time produces larger NOx formation takes place. Such effects of NO_X formation can be reduced by using advanced methods like EGR system to the engine, thus it could the possible solution to it.

So, this experimental investigation supports the production of biodiesel from peanut seed oil as a viable alternative to the diesel fuel.

References

Canan Kaya, Candan Hamamci, Akin Baysal, Osman Akba, Sait Erdogan, Abdurrahman Saydut. (2009). Methyl ester of peanut (Arachis hypogea L.) seed oil as a potential feedstock for biodiesel production. *Renewable Energy* Pg. 1257–1260.

E.I.Bello and M.Agge. (2012) Biodiesel Production from Ground

nut Oil. *Journal of Emergine Trends in Engineering and Applied Sciences* (JETEAS) 3 (2): 276 – 280.

Linus N. Okoro, Sedoo V. Belaboh, Nwamaka R. Edoye, Bello Y. Makama (2011). Synthesis, Calorimetric and Viscometric Study of Groundnut oil Biodiesel and Blends, *Research Journal of Chemical Science Vol 1(3*). Pg. 49 – 57.

A. K. Azad, S. M. Ameer Uddin and M. M. Alam (2012). A Comprehensive Study of DI Diesel Engine Performance With Vegetable Oil: An Alternative Bio-Fuel Source of Energy, *International Journal of Automotive and Mechanical Engineering (IJAME)*, Volume 5, pp. 576-586.

A.S. Ramadhas, S. Jayaraj, C. Muraleedharan (2004). Use of vegetable oils as I.C engine fuels – a review. *Renewable Energy 29* Pg. 727–742.

B.K. Barnwal, M.P. Sharma (2005). Prospects of biodiesel production from vegetable oils in India. Renewable and Sustainable Energy Reviews9 Pg. 363–378.

A. Ramaraju and Ashok Kumar T. V (2011), Biodiesel Development from High Free Fatty Acid Punnakka Oil, *ARPN Journal of Engineering and Applied Sciences*, VOL. 6, NO. 4.

BK Venkanna, Reddy CV (2009) Biodiesel production and optimization from Calophyllum inophyllum Linn oil (honne oil) – a three stage method. *Bioresource Technology 2009;*100(21):5122–5.

PK Sahoo, Das LM, Babu MKG, Naik SN.(2007) Biodiesel development from high acid value polanga seed oil and performance evaluation in a CI engine. *Fuel 2007*;86(3):448–54.

H.C.Ong, T.M.I Mahlia, H.H Masjuki, R.S. Norhasyima.(2011) Comparison of palm oil, Jatropha curcas and Calophyllum inophyllum for biodiesel: A review. *Renewable and Sustainable Energy Reviews* 15 (2011) 3501–3515.

PK Sahoo, Das LM, Babu MKG, Arora P, Singh VP, Kumar NR,(2009) et al. Comparative evaluation of performance and emission characteristics of Jatropha, Karanja and Polanga based biodiesel as fuel in a tractor engine. *Fuel 2009;*88(9):1698–707.

Milan D. TOMI], Lazar Dj. SAVIN, Radoslav D. MI]I],Mirko Dj. SIMIKI], and Timofej FFURMAN (2013). *Thermal Science* Vol. 17, No. 1, pp. 263-278.

G.X.Chu, Q.R.Shen & J.L.Cao.(2004) Nitrogen fixation and N transfer from peanut to rice cultivation in aerobic soil in an intercropping system and its effect on soil N fertility. *Plant and soil* 263: 17-27.

Friday JB, Okano D. (2006) Species profiles for Pacific Island Agroforestry: Calophyllum inophyllum (kamani). Hawaii, USA: *Permanent Agriculture Resources (PAR).*

A.S. Silitonga, A.E. Atabani, T.M.I. Mahlia, H.H.Masjuki, I.A.Badruddin. (2011). A compartive analysis of physical and chemical properties of Jatropha curcas.L, Calophyllum Inophyllum. L and Sterculia Feotida .L oil. *IGEC-6* – 2011 – 102.

Karmakar A, Karmakar S, Mukherjee S. (2010) Properties of various plants and animals feedstocks for biodiesel production. *Bioresource Technology 2010*;101(19):7201–10.

Canan Kaya, Candan Hamamci, Akin Baysal, Osman Akba, Sait Erdogan, Abdurrahman Saydut. (2009). Methyl ester of peanut (Arachis hypogea L.) seed oil as a potential feedstockfor biodiesel production. *Renewable Energy* Pg. 1257–1260.

G.H. Abd-Alla, H.A. Soliman, O.A. Badr, M.F. Abd-Rabbo.(2001). Effects of diluents admissions and intake air temperature in exhaust gas recirculation on the emission of an indirect injection dual fuel engine. *Energy conversion and Management 42* Pg. 1033-1045.

M.S. Reddy, C.N. Floyd , R.W.Willey. Groundnut in intercropping system Martine van Wolfswinkel. *Intercropping of Annual food crops.* http://www.allindiary.org/pool/resources/intercropping.pdf