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Experimental Investigation on the Performance and Emission Characteristics of a CI Engine with Rice Bran Biodiesel Blends

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Abstract:
It is always needed that to find an alternate of Diesel due to its price fluctuations and depletion rate. Biodiesel is the proven technology for a quite long time. As a most populated country, in India biodiesel from a non edible source is the preferred one and environmental accepted. Among the various alternative fuels, vegetable oil is a better option for diesel engine due to several advantages as renewable, environ- friendly and produced easily in rural areas. However, direct use of vegetable oil creates some durability problems so it is better to use it after converting into biodiesel as biodiesel (B.D.) is receiving increased attention as an alternative, non-toxic, biodegradable and renewable diesel fuel. Among various vegetable oils, rice bran oil is an underutilized non-edible vegetable oil which is available in large quantities in rice cultivating countries like India and a very little research has been done to utilize this oil as a replacement for mineral diesel. Rice bran is a byproduct is considered to be non edible source. Rice bran oil methyl esters (RME) were prepared using transesterification process. The property test will be take on rice bran oil and also calculate the performance and emission test take different percentage blended with diesel in diesel engine.

Key words: Diesel, non edible, biodiesel, Rice bran oil methyl esters (RME), performance and emission test

1. INTRODUCTION

Energy is an essential requirement for economic and social development for any country but, with advent of industrial revolution and sky rocketing of petroleum fuel costs in present day has led to growing interest in alternative fuels which can be produced from locally available resources within the country such as alcohol, biodiesel, vegetable oils etc in order to provide a suitable substitute to diesel for a compression ignition (CI). Currently the vegetable oils are the promising alternative fuel to diesel oil since they are renewable, biodegradable and clean burning fuel having similar properties as that of diesel. The most commonly used method to make vegetable oil suitable for use in CI engines is to convert it into biodiesel. The estimated yield of crude rice bran oil (RBO) in India is about 4, 00,000 tons of which only 50% is of edible grade, 50% of the total available rice bran oil is left unutilized due to presence of active lipase in bran, which hydrolyses the triglyceride to fatty acids and glycerol, as a result the Free Fatty Acid (FFA) content increases making it difficult to refine, due to the presence of tightly associated wax. Due to lack of economic stabilization, most of the bran is used as animal feed or for industrial application. One of the best ways for the potential utilization of RBO is to extract biodiesel from it; very little research has been done to utilize this oil as a replacement for mineral diesel. Keeping the point in view, this study was conducted on performance evaluation of rice bran biodiesel in small size agricultural diesel engines.

1.1 ALTERNATIVE FUELS

Alternative fuels include gaseous fuels such as hydrogen, natural gas, and propane; alcohols such as ethanol, methanol, and butanol; vegetable and waste-derived oils; and electricity. These fuels may be used in a dedicated system that burns a single fuel, or in a mixed system with other fuels including traditional gasoline or diesel, such as in hybrid-electric or flexible fuel vehicles.

1.1.1 Ethanol

An alcohol-based alternative fuel made by fermenting and distilling crops such as corn, barley or wheat. It can be blended with gasoline to increase octane levels and improve emissions quality. *Positive*: Materials are renewable. *Negative*: Ethanol subsidies have a negative impact on food prices and availability.

1.1.2. Natural Gas

Natural gas is an alternative fuel that burns clean and is already widely available to people in many countries through utilities that provide natural gas to homes and businesses. *Positive*: Cars and trucks with specially designed engines produce fewer harmful emissions than gasoline or diesel. *Negative*: Natural gas production creates methane, a greenhouse gas that is 21 times worse for global warming than CO2.

1.1.3 Electricity

Electricity can be used as a transportation alternative fuel for battery-powered electric and fuel-cell vehicles. Battery powered electric vehicles store power in batteries that are recharged by plugging the vehicle into a standard electrical source. Fuel-cell vehicles run on electricity that is produced through an electrochemical reaction that occurs when hydrogen and oxygen are combined. *Positive*: Electricity for transportation is highly efficient, and we already have an extensive electricity network. In the case of fuel cells, they produce electricity without combustion or pollution. *Negative*: Much electricity is generated today from coal or natural gas, leaving a bad carbon footprint. (Nonetheless, electric vehicles are still the greenest option around when it comes to cars.)

1.1.4 Hydrogen
Hydrogen can be mixed with natural gas to create an alternative fuel for vehicles that use certain types of internal combustion engines. Hydrogen is also used in fuel-cell vehicles that run on electricity produced by the petrochemical reaction that occurs when hydrogen and oxygen are combined in the fuel "stack." *Positive*: No bad emissions. *Negative*: Cost. And also the lack of fueling infrastructure and difficulty of putting it in place.

1.1.5 Propane
Propane—also called liquefied petroleum gas or LPG—is a byproduct of natural gas processing and crude oil refining. Already widely used as a fuel for cooking and heating, propane is also a popular alternative fuel for vehicles. *Positive*: Propane produces fewer emissions than gasoline, and there is also a highly developed infrastructure for propane transport, storage and distribution. *Negative*: Natural gas production creates methane, a greenhouse gas that is 21 times worse for global warming than CO2.

1.1.6 Biodiesel
Biodiesel is an alternative fuel based on vegetable oils or animal fats, even those recycled after restaurants have used them for cooking. Vehicle engines can be converted to burn biodiesel in its pure form, and biodiesel can also be blended with petroleum diesel and used in unmodified engines. *Positive*: Biodiesel is safe, biodegradable, reduces air pollutants associated with vehicle emissions, such as particulate matter, carbon monoxide and hydrocarbons. *Negative*: Limited production and distribution infrastructure.

1.1.7 Methanol
Methanol, also known as wood alcohol, can be used as an alternative fuel in flexible fuel vehicles that are designed to run on M85, a blend of 85 percent methanol and 15 percent gasoline, but automakers are no longer manufacturing methanol-powered vehicles. *Positive*: Methanol could become an important alternative fuel in the future as a source of the hydrogen needed to power fuel-cell vehicles. *Negative*: Automakers are no longer manufacturing methanol-powered vehicles.

1.1.8. P-Series Fuels
P-Series fuels are a blend of ethanol, natural gas liquids and methyltetrahydrofuran (MeTHF), a co-solvent derived from biomass. P-Series fuels are clear, high-octane alternative fuels that can be used in flexible fuel vehicles. *Positive*: P-Series fuels can be used alone or mixed with gasoline in any ratio by simply adding it to the tank. *Negative*: Manufacturers are not making flexible fuel vehicles.

2. PROBLEM DESCRIPTION

At present, about 80% of the world's demand for transportation fuels- road, rail, air and sea- are met by derivatives from the fossil fuels such as petroleum and diesel. Due to the scarcity of conventional fuels and the crude oil, the price was going up day to day and there will be no more conventional fuels in future and also increasing the environmental pollution by the usage of crude oils, there is a need for the search of alternative fuel sources for the automobile applications. The need for alternative fuels has been increasing in today's world due to greater depletion of natural petroleum reserves and increasing exhaust emissions from internal combustion engines leading to environmental pollution. Compression ignition engine generally uses diesel as the fuel for combustion which expels more power and better efficiency. But it ultimately leads to environmental hazards like HC, CO and NOx emission. As an opportunity to reduce the level of pollution, various alternate fuels like producer gas, biogas, alcohols, vegetable oils Therefore in the present investigation the oil taken is the rice bran oil which was obtained by the waste rice husk.

EXPERIMENTATION

5.1 RICE BRAN OIL
Rice bran oil is a non-conventional, inexpensive and low-grade vegetable oil. Crude rice bran oil is also source of high value added by-products. Thus, if the by-products are derived from the crude rice bran oil and the resultant oil is used as a feedstock for biodiesel, the resulting biodiesel could be quite economical and affordable.

Figure 5.1 rice bran oil

Rice bran oil is the oil extracted from the germ and inner husk of rice. It is notable for its very high smoke point of 490° F (254° C) and its mild flavor, making it suitable for high-temperature cooking methods such as stir frying and deep frying. It is popular as cooking oil in several Asian countries, including Japan and China. Rice bran oil contains a range of fats, with 47% of its fats monounsaturated, 33% polyunsaturated, and 20% saturated.

5.2 BIO DIESEL PREPARATION
Biodiesel has many environmentally beneficial properties. The main benefit of biodiesel is that it can be described as 'carbon neutral'. This means that the fuel produces no net output of carbon in the form of carbon dioxide (CO2). This effect occurs because when the oil crop grows it absorbs the same amount of CO2 as is released when the fuel is combusted. In fact this is not completely accurate as CO2 is released during the production of the fertilizer required to fertilize the fields in which the oil crops are grown. Fertilizer production is not the only source of pollution associated with the production of biodiesel, other sources include the esterification process, the solvent extraction of the oil, refining, drying and transporting. All these processes require an energy input either in the form of electricity or from a fuel, both of which will generally result in the release of green house gases. To properly assess the impact of all these sources requires use of a technique called life cycle analysis. Our section on LCA looks closer at this analysis. Biodiesel is rapidly biodegradable and completely non-toxic, meaning spillages represent far less of a risk than fossil diesel spillages. Biodiesel has a higher flash point than fossil diesel and so is safer in the event of a crash.
As mentioned above biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste oils. There are three basic routes to biodiesel production from oils and fats:

- Base catalyzed transesterification of the oil.

- ❖ Direct acid catalyzed transesterification of the oil.
- ❖ Conversion of the oil to its fatty acids and then to biodiesel.

If you were out playing basketball and rolled your ankle, you may take aspirin to relieve the pain and swelling. Aspirin relieves swelling and pain with a compound called salicylic acid, yet the carboxylic group in salicylic acid greatly irritates the stomach. Chemists discovered that if it is combined with acetic acid then it forms an ester, acetylsalicylic acid, which reduces the irritation on the stomach. This is the compound that we take as aspirin. The reaction that combined the salicylic acid and acetic acid to form acetylsalicylic acid is called esterification. **Esterification** is the process of forming esters from carboxylic acids. An **ester** is when a carbon is connected to two oxygens, but one of the oxygens isn't connected to anything else (so it is double-bonded to the carbon), while the other oxygen is connected to another carbon. Here is the general formula for an ester ('R' refers to a carbon chain) Almost all biodiesel is produced using base catalyzed transesterification as it is the most economical process requiring only low temperatures and pressures and producing a 98% conversion yield. For this reason only this process will be described in this report.

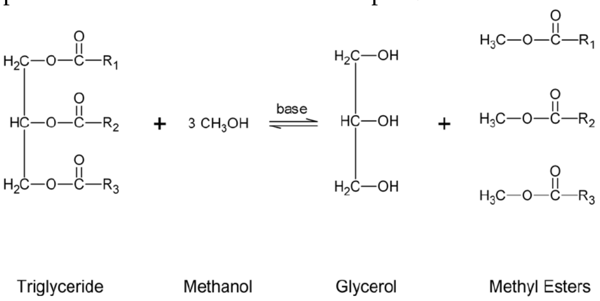


Figure 5.2 Transesterification process

The Transesterification process is the reaction of a triglyceride (fat/oil) with an alcohol to form esters and glycerol. A triglyceride has a glycerine molecule as its base with three long chain fatty acids attached. The characteristics of the fat are determined by the nature of the fatty acids attached to the glycerine. The nature of the fatty acids can in turn affect the characteristics of the biodiesel. During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide. The alcohol reacts with the fatty acids to form the mono-alkyl ester, or biodiesel and crude glycerol. In most production methanol or ethanol is the alcohol used (methanol produces methyl esters, ethanol produces ethyl esters) and is base catalysed by either potassium or sodium hydroxide. Potassium hydroxide has been found to be more suitable for the ethyl ester biodiesel production, either base can be used for the methyl ester. A common product of the transesterification process is Rape Methyl Ester (RME) produced from raw rapeseed oil reacted with methanol. The figure below shows the chemical process for methyl ester biodiesel. The reaction between the fat or oil and the alcohol is a reversible reaction and so the alcohol must be added in excess to drive the reaction towards the right and ensure complete conversion.

5.3RICE BRAN OIL PREPARATION

5.3.1 Fatty Acid Ethyl Esters from Rice Bran Oil

Fatty acids esters are known to be good alternative fuels (biodiesel). Due to the economic reasons, the use of cheap materials as substrats for biodiesel is being preferred. In this case, rice bran oil, which can not to be evaluated as an edible oil, is an interesting substrat. Esterification of high-acidity rice bran oil with ethanol and sulfuric acid catalyst was investigated. The effects of free fatty acid (FFA) contents of rice bran oil and ethanol concentration on in-situ esterification were investigated and compositions of produced ethyl esters due to the conditions were determined**.**

5.3.2 Acid Catalyzed Trans-esterification of Rice Bran Oil for Bio-diesel Production

The high value of soybean oil or canola oil as a food product makes production of a cost-effective fuel very challenging. Use of edible oils as biodiesel feedstock cost about 60-70% of raw material cost. Nonedible, inexpensive, low-grade oils with value added byproducts is utmost important to make the biodiesel production economical. Rice bran oil ranks first among the non-conventional, inexpensive, low-grade vegetable oils. Furthermore, crude rice bran oil is a rich source of high value-added byproduct. Therefore, use of rice bran oil as raw material for the production of biodiesel not only makes the process economical but also generates value added bio-active compounds. Isolation and purification of these byproducts make the process attractive and remunerative.

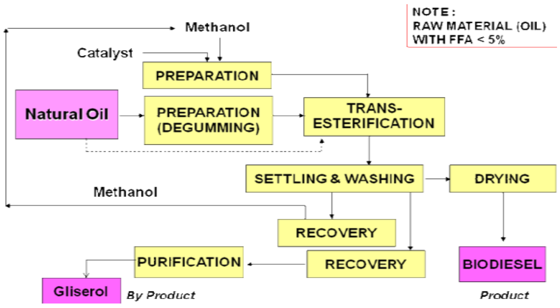


Figure 5.3 biodiesel production process

In the present investigation a systematic studies of transesterification of high free fatty acid rice bran oil was carried out to establish optimal reaction condition. It was found that acid-catalyzed methanolysis of fatty acids are faster than pure triglycerides or pure triglycerides plus 5% water. More than 99% of FA were converted to their corresponding FAME with 20 min of reaction times at temperature of boiling point of methanol otherwise almost for 6 hours reaction none of TG were converted. Effect of chain length and unsaturation of fatty acid on rate of esterification of fatty acid with methanol are equally reactive irrespective of difference in their chemical structures. Fatty acids from different sources shows similar conversions and change in the fatty acids composition has no effect on rate of methanolysis.

5.4 PROPERTIES OF RICE BRAN OIL

Table 5.1 Properties of Rice bran oil

S.No	PARAMETERS	RESULT OBTAINED FOR RBME	DIESEL
1.	Flash point by PMCC	218^{o}C	52 ^{o}C
2.	Fire point by PMCC	228^{o}C	56 ^{o}C
3.	Kinematic viscosity @ 40^{o}C	5.21 cst	2.60 cst
4.	Density @15^{o}C	0.8790 gm/ml	0.850 gm/ml
5.	Gross calorific value	8839 Kcal/ kg	4392 Kcal/ kg
6.	Conrad son carbon residue	0.13 %	0.17 %
7.	Ash content	0.02 %	0.01%

PERFORMANCE AND EMISSION TEST

Engine performance is an indication of the degree of success with which it does its assigned job *i.e.*, conversion of chemical energy contained in the fuel into useful work. In evaluation of engine performance certain basic parameters are chosen and effect of various operating conditions and modifications on these parameters are studied.

Figure 6.1 Test rig IC research engine

6.3 Data collection

There are five test fuels were used during performance test includes 100 % diesel, 25 % RBO blend with diesel, 50% RBO blend with diesel, 75 %RBO blend with diesel,100% RBO blend with diesel. The following tables shows the obtained data's from performance tests for various RBO diesel blends such as Brake power, Indicated power, Mechanical efficiency, brake mean effective pressure, brake thermal efficiency, indicated thermal efficiency, specific fuel consumption.

Table 6.1 Indicated power for various RBO Diesel blend

INDICATED POWER (kW)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	2.059992	2.059992	2.059992	2.059992	2.059992
40 %	3.099983	3.099983	3.099983	3.099983	3.099983
60 %	4.139975	4.139975	4.139975	4.139975	4.139975
80 %	5.179966	5.179966	5.179966	5.179966	5.179966
100%	6.219958	6.219958	6.219958	6.219958	6.219958

Table 6.2 Brake power for various RBO diesel blend

BRAKE POWER (kW)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	1.039992	1.039992	1.039992	1.039992	1.039992
40 %	2.079983	2.079983	2.079983	2.079983	2.079983
60 %	3.119975	3.119975	3.119975	3.119975	3.119975
80 %	4.159966	4.159966	4.159966	4.159966	4.159966
100 %	5.199958	5.199958	5.199958	5.199958	5.199958

Table 6.3 Mechanical efficiency for various RBO diesel blends

MECHANICAL EFFICIENCY (%)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	0.504852	0.504852	0.504852	0.504852	0.504852
40 %	0.670966	0.670966	0.670966	0.670966	0.670966
60 %	0.753622	0.753622	0.753622	0.753622	0.753622
80 %	0.803088	0.803088	0.803088	0.803088	0.803088
100 %	0.836012	0.836012	0.836012	0.836012	0.836012

Table 6.4 Brake thermal efficiency for various RBO diesel blends

BRAKE THERMAL EFFICIENCY (%)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	11.96772	12.43551	11.14006	10.93318	12.91606
40 %	19.71518	20.19437	18.01336	15.30864	19.38117
60 %	23.74104	22.98152	23.79314	20.15368	22.85606
80 %	28.02046	26.60814	24.90729	23.09849	26.79579
100 %	31.15888	30.81519	27.90172	26.39514	28.67637

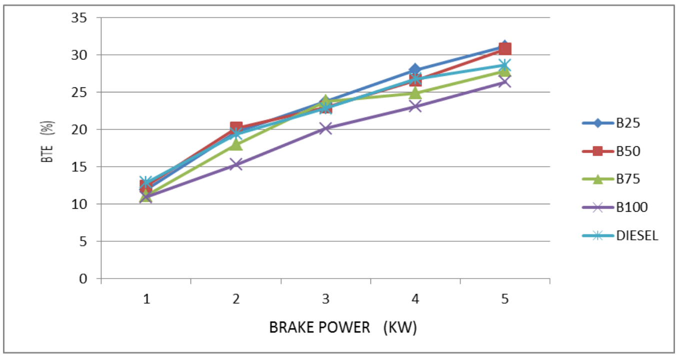


Table 6.6 Indicated thermal efficiency for various RBO diesel blends

INDICATED THERMAL EFFICIENCY (%)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	23.70538	24.63198	22.06597	21.65618	25.58383
40 %	29.38328	30.09746	26.8469	22.81582	28.88548
60 %	31.5026	30.49477	31.57174	26.74243	30.3283
80 %	34.89091	33.13231	31.01441	28.76211	33.36596
100 %	37.27087	36.85976	33.37479	31.57269	34.30139

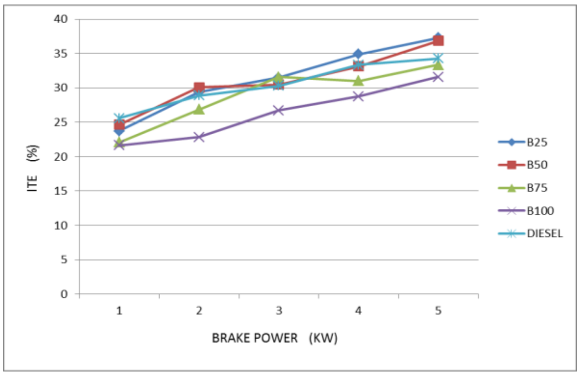


Table 6.7Brake specific fuel consumption for various RBO diesel blends

BRAKE SPECIFIC FUEL CONSUMPTION (kg/kWh)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	0.676342	0.650899	0.726591	0.74034	0.626683
40 %	0.41056	0.400818	0.449348	0.528739	0.417636
60 %	0.34094	0.352208	0.340193	0.401627	0.354141
80 %	0.28887	0.304203	0.324976	0.350424	0.302072
100 %	0.259774	0.262671	0.290099	0.306657	0.282263

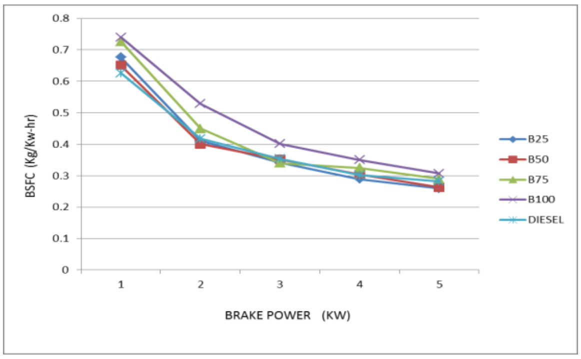


Table 6.7 Indicated specific fuel consumption for various RBO diesel blends

INDICATED SPECIFIC FUEL CONSUMPTION (kg/kWh)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	0.341453	0.328608	0.366821	0.373762	0.316382
40 %	0.275472	0.2689935	0.301497	0.354766	0.280219
60 %	0.25694	0.265431	0.256377	0.302675	0.266888
80 %	0.231988	0.244301	0.260984	0.281412	0.242591
100 %	0.217174	0.219596	0.242526	0.256369	0.235975

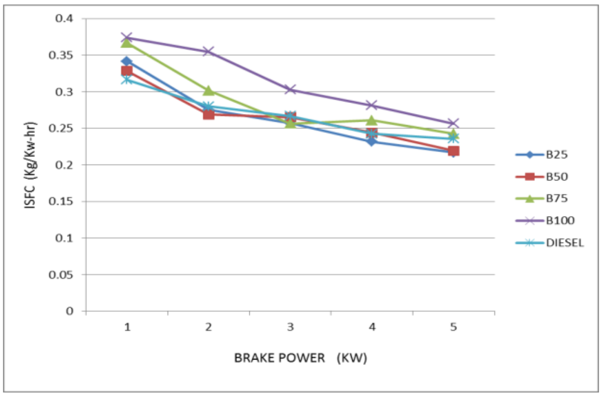


Table 6.8 carbon monoxide (CO) for various RBO diesel blends

CARBON MONOXIDE (CO)(% BY VOLUME)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	0.07	0.06	0.05	0.05	0.09
40 %	0.07	0.05	0.05	0.06	0.09
60 %	0.08	0.09	0.08	0.1	0.07
80 %	0.1	0.12	0.12	0.12	0.12
100 %	0.32	0.24	0.27	0.34	0.36

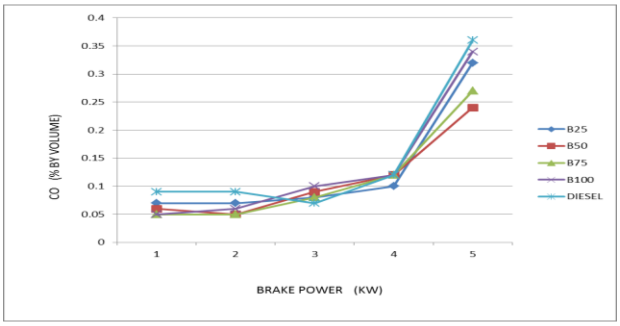


Table 6.9 hydrocarbons (HC) for various RBO diesel blends

HYDROCARBONS (HC) (ppm)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	47	56	57	48	35
40 %	52	62	60	52	70
60 %	57	61	61	54	83
80 %	61	67	67	62	100
100 %	67	69	69	67	154

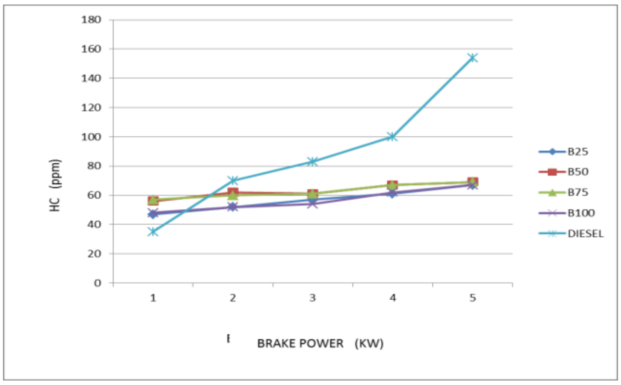


Table 6.10 Carbon dioxide (co$_2$) for various RBO diesel blends

CARBON DIOXIDE (CO_2) (% BY VOLUME)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	2.9	2.9	2.6	2.7	2.4
40 %	3.2	3.6	3.4	3.1	3.2
60 %	3.4	5.1	4.2	4.2	3.9
80 %	4.2	6.3	5.1	5.4	6.4
100%	5.1	6.8	5.4	6.1	7

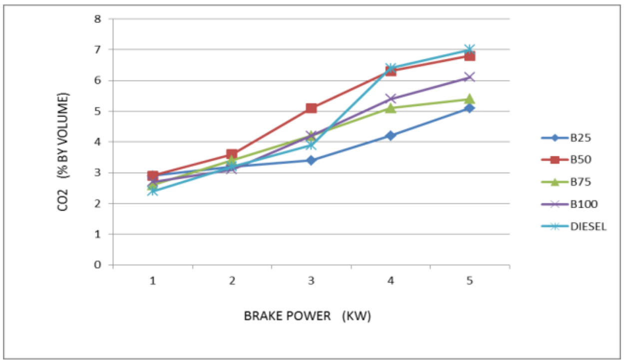


Table 6.11 Oxygen (O_2) for various RBO diesel blends

OXYGEN (O_2) (% BY VOLUME)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	16.5	16.1	16.9	16.13	18.26
40 %	15.32	15.7	15.14	15.42	17.04
60 %	14.12	14.41	19.72	14.12	15.04
80 %	13.02	13.1	13.1	13.82	14.81
100 %	11.1	10.24	11.24	12.6	12.1

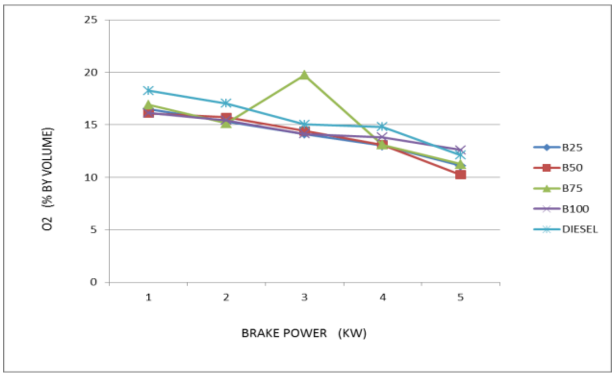
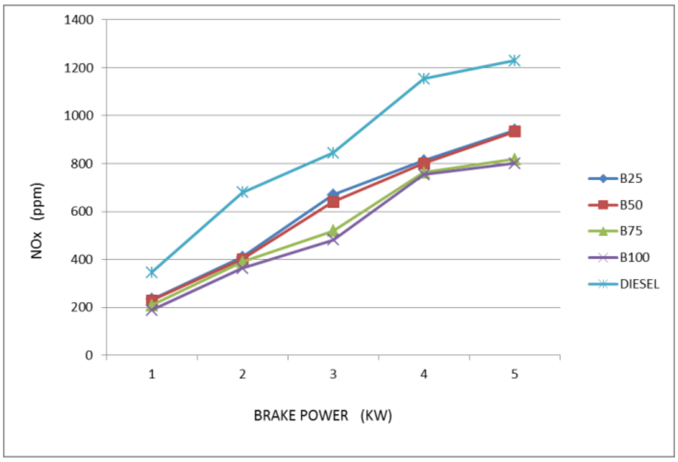


Table 6.12 Nitrogen oxide (NO_X) for various RBO diesel blends

NITROGEN OXIDE (NO_X) (% BY VOLUME)					
LOAD (kg)	25 % RBO Diesel blend	50 % RBO Diesel blend	75% RBO Diesel blend	100 % RBO Diesel blend	Diesel
20 %	234	230	209	189	346
40 %	410	401	389	364	680
60 %	640	640	520	482	845
80 %	812	801	763	754	1154
100 %	940	934	818	801	1230



7. CONCLUSION

In our work the Biodiesel was prepared from the non-edible oil of Rice brand oil by transesterification of the crude oil with methanol in the presence of NaOH as catalyst. A maximum conversion of 92% (oil to ester) was achieved at 65˚C. the received Rice brand oil is blended in different proportion 10%,30%, and 50%.the blends are subjected to performance and emission test rig engine the calculation are arrived

- Engine was able to run with 50% RB oil-diesel blend
- Engine fuelled with 50 % RB oil-diesel blend exhibits higher brake thermal efficiency (30.815%) when compared to pure diesel (28.673%).
- Engine fuelled with 50 % RB oil-diesel blend exhibits higher indicated thermal efficiency (36.85%) when compared to pure diesel (34.30%).
- Brake specific fuel consumption 75% and 100% RB oil-diesel blend exhibits higher indicated thermal efficiency (0.3066kg/ kw-hr) when compared to pure diesel (0.2822 kg/ kw-hr)
- Emission level is less compare to pure diesel. So, it's more suitable for alternate fuel in diesel engines.

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