ABHILASH O
RAJGOPAL M S
MRITYUNJAYASWAMY KM
and
RAVITEJ Y P

Enhancing the performance of preheated B20 vegetable seed oil by varying the compression ratio and using cerium oxide as a stabilizer

The main purpose of the present investigation is to effectively utilize the biofuel along with cerium oxide as a stabilizer powered with a single-cylinder variable compressible ratio diesel engine fuelled with the 20% (blend B20) waste vegetable seed biofuel (WVO). Ethyl-based esters production process from neutralized WVO is optimized by sodium hydroxide (NaOH) single-phase reaction to enhance the production of the biofuel. B20 WVO biodiesel behaviour is tested in a diesel engine by varying the compression ratio 16 and 18. Compression ratio 16 had better thermal efficiency and less CO_x *and* NO_x *emission when compared to compression ratio 18. 250 bar injection pressure and 19 injection timing were found to have better fuel efficiency and emission characteristics. The influence of cerium oxide as a stabilizer in both the engine performance and the produced emissions was evaluated. From the result, it is observed that the increase in injection pressure from 210 bar to 250 bar leads to an increase in brake thermal efficiency by 6.1%, mechanical efficiency increases by 4.4%, and a decrease in brake specific fuel consumption by 5.7%. The CO and HC emission decreases by 3.9% and 3.2% respectively then retarding the injection timing.*

Keywords: Compression, cerium oxide, vegetable seed biofuel, saturated compounds, thermal efficiency.

1.0 Introduction

Fried vegetable seed oil is a prospective source for non-conventional fuel production. Most of the petroleum substantial fuels are derived from fossil energy sources. Since it is a vegetable seed oil, it is labelled as an ecologically friendly source because it enclosed no sulphur amalgams and does not add to the environment's carbon dioxide level thus reducing the greenhouse gases impacts. Additionally being a used edible vegetable seed oil food versus fuel encounters will not arise especially in heavily uninhabited nations.

Messrs. Abhilash O, Rajgopal M S, Mrityunjayaswamy KM and Ravitej Y P, Department of Mechanical Engineering, Dayananda Sagar University, India. E-mail: Corresponding author:ravitemtech@gmail.com

Since waste vegetable seed oil can be procured from restaurants on daily basis, they are readily accessible all through the year the sustainability of the feedstock supply is guaranteed. Biodiesel comprises a combination of fatty acids monoalkyl esters (FAME) acquired by transesterification of vegetable oils or animal fats [2] with short-chain alcohol, such as methanol or ethanol [3], and catalyzed by acids or bases (usually NaOH or KOH) [4]. Compared to diesel derived from petroleum, biodiesel reduces carbon monoxide and hydrocarbons emissions and diminishes smoke formation [2,5,6]. In addition, biodiesel offers greater lubricity and biodegradability than diesel [5,6]. The absence of sulphur avoids the formation of infecting compounds, such as SO_2, related to the acid rain existence [7]. As biodiesel is made from plants that absorb CO_2 during their progress, it is clever thought that there is not a net addition of CO_2 concentration in the atmosphere due to biodiesel burning. On the other hand, escalations in fuel consumption and NO_x emissions have been reported by most investigators.

The main problems of neat biodiesel to be used in CI diesel engines are associated with the low oxidation stability for long-term storage and poor cold flow properties. Both of them are highly reliant on the type of feedstock and their fatty acids composition. Saturated compounds are liable for the poor cold flow properties of biodiesel, whereas unsaturated esters are mainly answerable for their oxidation [8]. Biodiesel can experience autoxidation in the presence of air and, therefore, the addition of antioxidants are usually essential to fulfill the quality requirements for biodiesel commercialization defined in different standards, according to the American Standards for testing materials.

This study aims to test waste vegetable biodiesel treated with cerium oxide additive mixed properly with the help of a high-speed emulsifier in a variable compression direct injection diesel engine to assess the influence of the additive on the performance of the engine and the produced emissions. Engine performance was analyzed at six different loads and constant speed conditions. The biofuel was produced from the facility available at Siddganga Institute of Technology, Tumkur. Standard B20 blend waste vegetable seed oil was considered for experimentation purposes. The biodiesel was preheated in the oven before it is being filled in the fuel tank. The experiment was conducted for two (16 and 18) different compression ratios, three different injection pressures (210 bar, 230 bar, 250 bar), and four different injection timings (19, 21, 23, 25 before TDC) to study the influence of performance parameters and emission characteristics. Emissions characteristics readings were taken with the help of a smoke meter and five gas analyzer. The behaviour of the additive treated B20 blend biofuel was compared to neat diesel, vegetable biofuel by preparing standard B20 blend waste vegetable biofuel.

2.0 Materials and methods

2.1. Fuels

The main fuel in this work was biodiesel manufactured from waste vegetable seed oil procured from restaurants. The biodiesel was treated with an additive (cerium oxide). Commercially available diesel fuel, B20 blend waste vegetable biofuel without additive was considered for comparison purposes in the study of the performance and emissions of biodiesel with additives. Additionally, the experiment was repeated for 1gm and 2gm addition of additive for comparison purposes to study whether any increase in addition of additives leads to increased performance and reduced emissions of the biofuel.

2.2 Biodiesel production

The biodiesel used in the study was produced in the research lab of Siddaganaga Institute of Technology, Tumkur, by catalytic transesterification of waste vegetable seed oil (acidity less than 0.4) with an excess of methanol (molar ratio: methanol=1:7) and NaOH as catalyst (2%wt of oil mass). Fuel was optimized by sodium hydroxide (NaOH) single-phase reaction to enhance the production of the biofuel. Cold flow properties are increased and sediments are removed by subjecting the fuel to double hot water treatment and by the proper drying process, to remove moisture content in the fuels. Several batches of biodiesel were prepared to get the amount needed for this work, around 13 liters.

2.3. Preparation of additive

The additive was procured from a private company. After preparation biodiesel was mixed with cerium oxide additive properly as biodiesel and additives were not completely mixable the insoluble fraction of additive was removed by emulsification with the help of a 15000 rpm emulsifier after the extraction process. The final additive was mainly composed of biodiesel, with a concentration higher than 80%. For comparison purposes, the experiment was repeated for two different weights of additives.

2.4 Characterization

Before the engine, the fuels were characterized in merino testing laboratories, Bengaluru. The extraction of biodiesel was done by the mechanical expelling method. The yield obtained was 60%. The result of testing was done for neat diesel and biodiesel for comparison purposes. The results included sulphate ash, sediments, viscosity, kinematic viscosity, sulfur, total acid number, saphonification value, iodine value, flash point, fire point. The results of all testing for each diesel and biodiesel sample are given in Table 1.

Table 1: Characterization of diesel and biodiesel sample

	Characterization	Diesel sample	Biodiesel sample
1	Sulphate ash	0.01%	nil
2	Sediments	0.8%	0.13%
3	Calorific valve	45.5 MJ/kg	42.3 MJ/kg
4	Kinematic viscosity	4.9mm^2/s	4.5mm^2/s
5	Sulphur	0.4%	0.011%
6	Total acid number	0.56mg KOH/gm	23.2mg KOH/g
7	Saphonification value	240g KOH/g	256g KOH/g
8	Iodine value	120	34.6
9	Flash point	61°C	250°C
10	Density	876kg/m^3	933kg/m^3

From the table density and flash point are found to be higher than the diesel fuel, hence waste vegetable seed oil is extremely safe for handling the fuel from one place to another place. Sulphur content is less, results in less SO_x emissions. The high density of biodiesel may result in poor starting in cold conditions. Higher carbon deposits from waste vegetable oil may lead to higher deposition of carbon in the chamber of the compression ignition engine. Frequent cleaning is necessary for removing the carbon residue from the chamber of the engine. The calorific value of the fuel is closer to the neat diesel because of the higher oxygen content in the fuel. The acid number of biodiesel is less than the prescribed ASTM standards; therefore there is no problem of corrosion of automotive parts. The iodine value of the fuel is well within the prescribed limit of BS V1 norms which will be implemented in India from April 2020. It is perceived that the viscosity of waste vegetable seed oil decreases remarkably with increasing temperature and it becomes close to diesel at a temperature above 800°C.

2.5 Diesel engine test rig

The experiment was conducted in a VCR Kirlosker installed in a test bench coupled with an eddy current dynamometer, which allows the measurement of speed and load with an accuracy of ±10 rpm and ±0.7 Nm, respectively. Technical specifications are provided in the Table 2. A schematic diagram of the test bench is shown in Fig.1. The configuration of the engine was maintained as original, but the experiment was conducted by replacing the injectors since the experiment is conducted for three different compression ratios (16 and18), different injection pressures (210, 230 and 250 bar), and the experiment is conducted for different injection timings (19, 21, 23 and 25) before TDC. To avoid any

TABLE 2: DIESEL ENGINE SPECIFICATIONS

Characteristics	Kirloskar with variable compression ratio
Original fuel	Diesel
No of cylinders	One
Cubic capacity	661cc
Bore×stroke	87.5mm×110mm
Compression ratio	12-18
Valve timing	0-250 before TDC

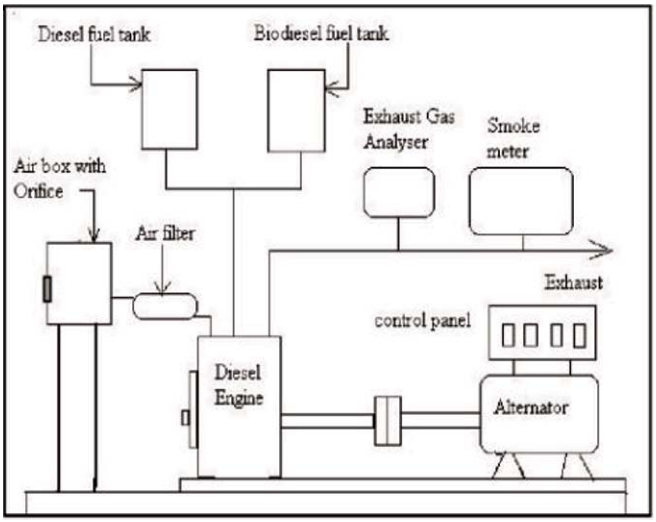

Fig.1: Schematic diagram of the engine test bench

thermal stress and preserve the mechanical system, the maximum absolute boost pressure was limited to 1.7 bar.

Fuel consumption was measured with a volumetric liquid fuel flowmeter. The flowmeter allowed the determination of the intake air mass. Ambient conditions, air temperature, and pressure at the intake manifold were monitored. Exhaust, fuel, coolant, and oil temperatures were also measured, together with the torque and engine speed. The gaseous emission was measured with the help of five gas analyzers. The values of opacity, expressed as mg of soot per m^3, were provided by a smoke-meter for diesel engines (Table 2).

2.6. EXPERIMENTAL PROCEDURE

Two different kinds of experiments were carried out on the engine test bench. First, the influence of the type of fuel and the presence of the additive in the general performance of the diesel engine was investigated by running the engine at six different loads and maintaining the constant speed with three different fuels. The experiment was conducted for two different compression ratios (16 and 18), three different injection pressures (210, 230 and 250 bar), and 3 injection timing (19, 21, 23 and 25 before TDC). The one with better performance and reduced emissions were taken for further analysis of performance and emissions with the addition of cerium oxide as a stabilizer. The evolution of the brake power (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), indicated thermal efficiency (ITE), volumetric efficiency, and heat absorbed by brake power, exhaust gas, and water jacket was analyzed.

The experiment was carried out for a combination of different loads that represent most of the possible working conditions of the engine. Gaseous emissions, including CO, hydrocarbons, NO_x and CO_2, and opacity factors were measured with the help of five gas analyzers and a smoke meter. To assure a proper reproducibility of the data, data acquisition was performed according to the directive (exhaust gas flow rate precision better than 2.5%, engine speed held within 50 rpm of the set value) and gas analyzers were calibrated before each test run with an accuracy ranging from 10 to 50 ppm for CO, 0.2–0.4% for CO_2, 2–8 ppm for HC, and 2–5 ppm for NO_x, depending on the measured range for each pollutant.

3.0 Results and discussions

In the first step, the B20 biodiesel was tested with two different compression ratios (16 and 18) by maintaining injection pressure (IP) 210 bar and injection timing (IT) 23 before TDC. B20 biodiesel with compression ratio (CR) 16

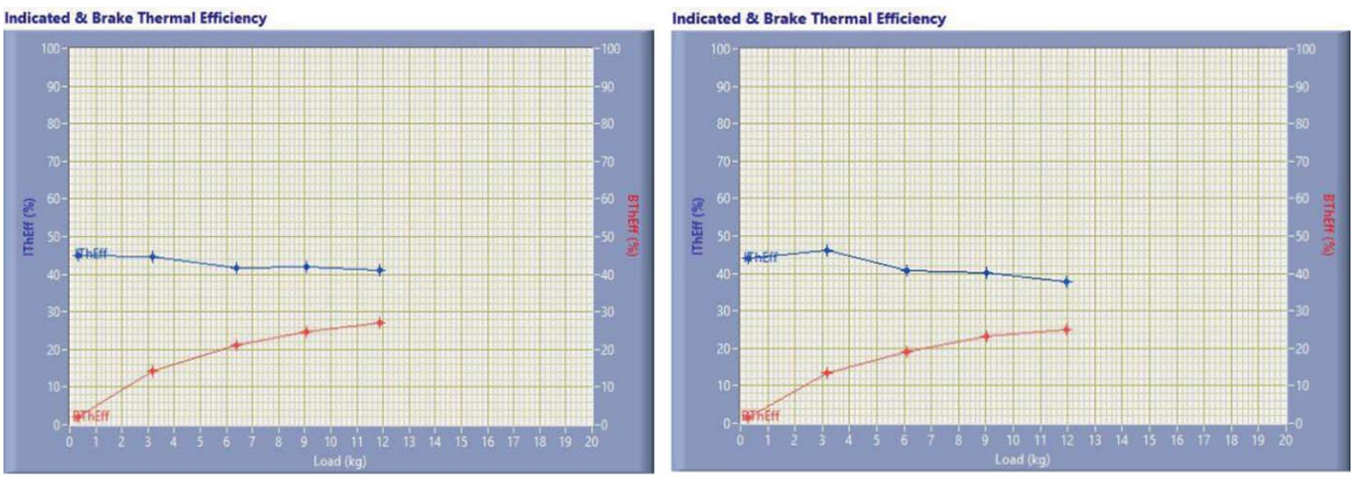

Fig.2: Variation of Ith and brake bth at different loads for CR 18 and CR 16

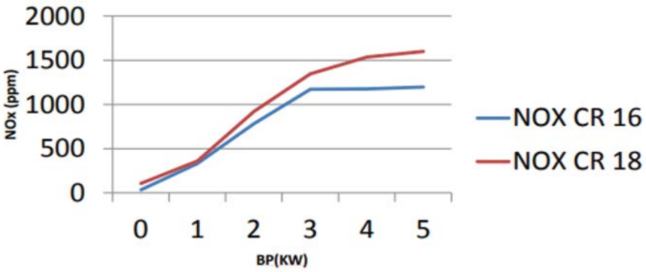

Fig.3: NO_x emission

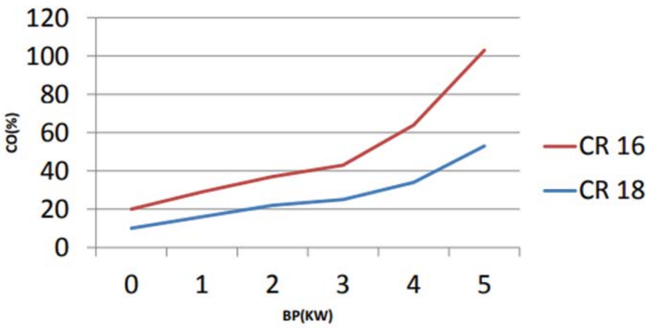

Fig.4: CO_x emission

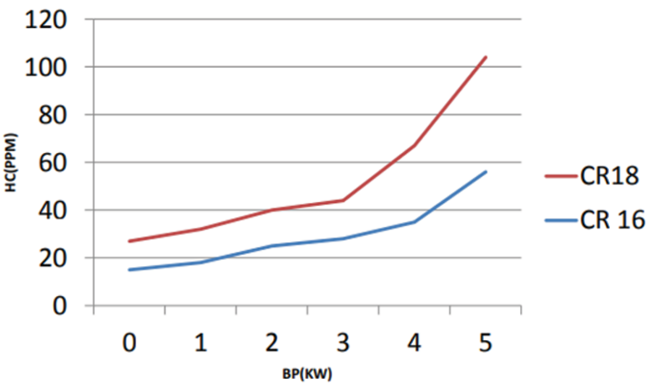

Fig.5: HC emission

showed better thermal efficiency and reduced emissions. Fig.2 shows the graph of variation of brake thermal efficiency and indicated thermal efficiency. From the graph, it is observed that B20 biodiesel with compression ratio 16 shows better brake thermal efficiency (both) and indicated thermal efficiency (ith) at different loads when compared to compression ratio 18. The emission results have been discussed in Fig.3. From the graph, it is absorbed that brake thermal efficiency as well as indicated thermal efficiency with CR 16 showed better results than CR18 at different loads. From Figs.3, 4, and 5 it can be seen that carbon monoxide (CO_x), oxides of nitrogen (NO_x), hydrocarbon (HC) emissions for biodiesel with CR16 showed fewer emissions when compared to biodiesel with CR18. Hence CR16 is taken as the standard compression ratio for different injection pressures and injection timings before the addition of a stabilizer to the biodiesel.

In the second step, the experiment was conducted for three different injection pressures CR16 IP 250 bar, CR16 230 bar IP and CR16, and IP 210 bar, and four injection timings (19, 21, 23 and 25) before TDC for comparison purposes. The brake thermal efficiency and indicated thermal efficiency at both injection pressures are shown in Figs.6 to 9. From the figure, it can be observed that IP 250 bar and 19 IT before TDC biodiesel showed better results and less emission CO_x, NO_x, HC emissions than 230bar and 210bar. Hence B20 biodiesel at 250 bar has been considered for further analysis.

4.0 Conclusions

The investigational result displays the performance and emission characteristics of B20 waste vegetable seed biodiesel and diesel and also gives the comparison to that of the base diesel. From the investigational result, biodiesel if used as fuel replacements in a diesel engine it will safeguard the environment using lower emissions compared to diesel. The followings were the conclusions arrived at regarding emission and performance.

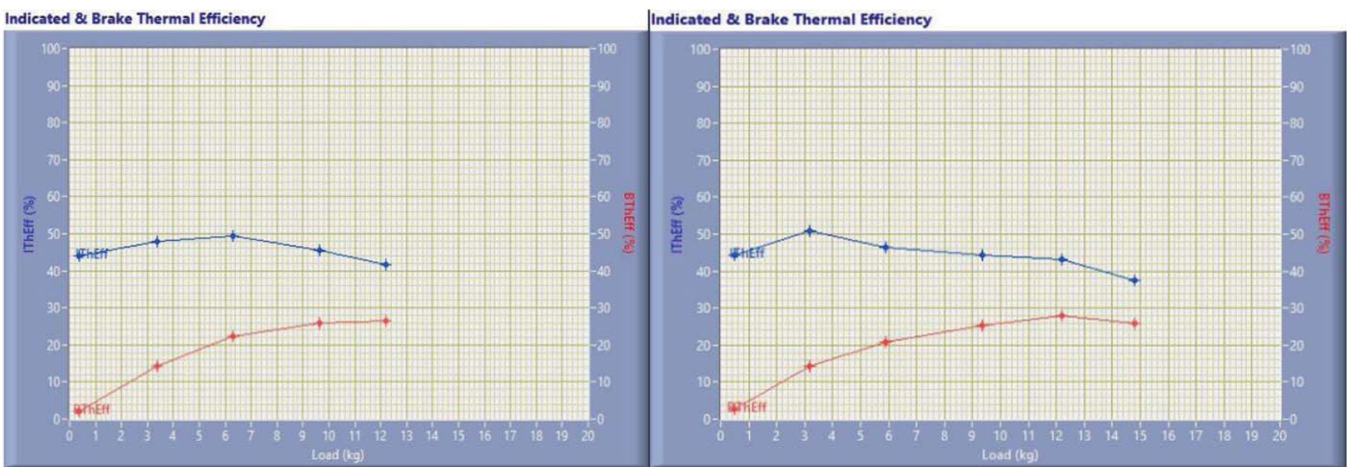

Fig.6: Variation of Ith and brake Bth at different loads at IP 250 bar IT 19 and IP 230 IT19

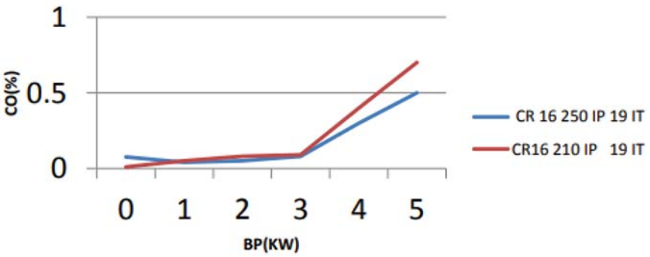

Fig.7: CO_x emission

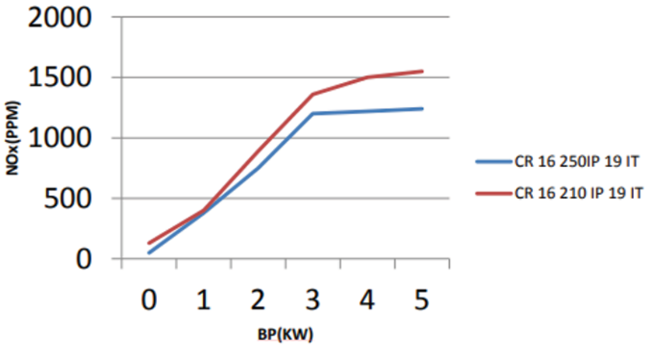

Fig.8: NO_x emission

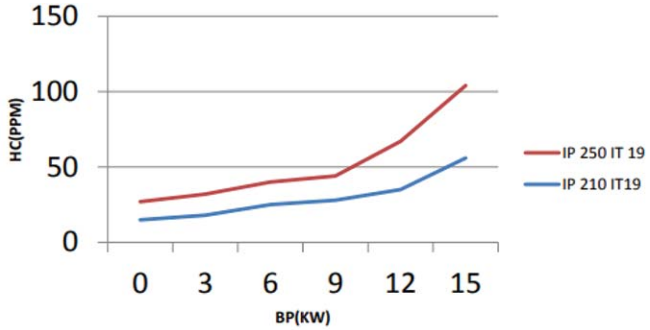

Fig.9: HC emission

Waste vegetable seed oil can be used as biodiesel for large-scale production. The fuel consumption is higher on the fuel blend due to the lower gross heat of combustion. The 20% bio diesel blend at 250 bar IP and 19 IT before TDC was found to be more suitable to run the engine than other injection pressures and injection timings due to improved brake thermal efficiency, mechanical efficiency, and reduced specific fuel consumption. There is an increase of BSFC by 5% and a decrease in bth by 7% when compared to diesel. The B20 biodiesel gives lower CO and HC emissions than diesel at all injection pressure and timing.

References

[1] Joon Ching Juan, Damayanti Agung Kartika, Ta Yeong Wu, Taufiq-Yap Yun Hin, (2011): "Biodiesel production from jatropha oil by catalytic and non-catalytic approaches: An overview", *Bioresource Technology* 102, 452–460.

[2] Avinash kumar Agarval. (2007): "Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines", *Progress in Energy and Combustion Science* 33, 233-271.

[3] Aziz Elbehri Anna Segerstedt and Pascal Liu. (2013): "Biofuels and the sustainability challenge: A global assessment of sustainability issues, trends and policies for biofuels and related feedstocks", Trade and Markets Division Food and Agriculture Organization of the United Nations Rome.

[4] Amit Aradhey. (2016): "USDA Foreign Agricultural Service. GAIN Report. Global Agricultural Information Network. India Biofuels Annual", *GAIN Report No.* 6088, 24.06.2016.

[5] Gaurav Dwivedi, Mahendra Pal Sharma. (2016), "Experimental investigation on the thermal stability of Pongamia Biodiesel by thermogravimetric analysis", *Egyptian Journal of Petroleum* 25, 33–38.

[6] Sanjib Kumar Karmee, Anju Chadha, (2005): "Preparation of biodiesel from crude oil of Pongamia pinnata", *Bioresource Technology* 96, 1425–1429.

[7] Ghadge SV, Raheman H. (2005): "Biodiesel production from mahua (Madhuca Indica) oil having high free fatty acids", *Biomass and Bioenergy* 28, 601–605.

[8] M.S. Khayoon, M.A. Olutoye, B.H. Hameed, (2012): "Utilization of crude karanj (Pongamia pinnata) oil as a potential feedstock for the synthesis of fatty acid methyl esters", *Bioresource Technology* 111, 175-179.