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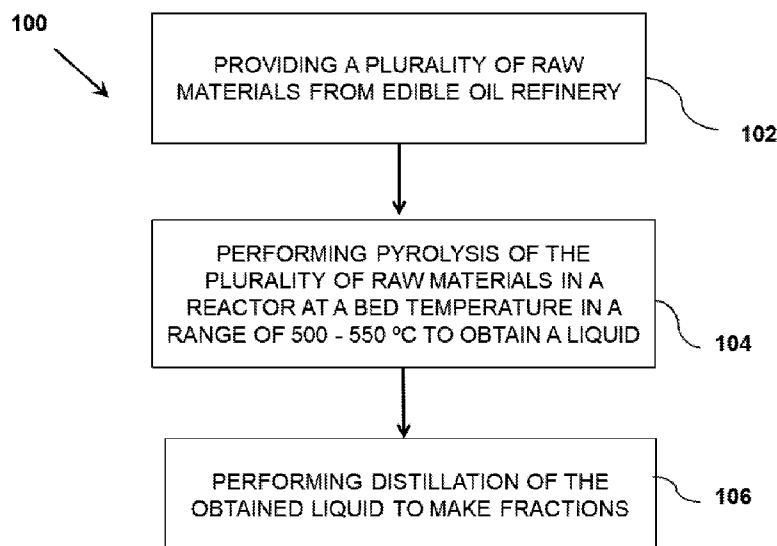


Fig.1

(57) Abstract: A method for the production of biofuel, the method comprises the steps of providing a plurality of raw materials from edible oil refinery, performing pyrolysis of the plurality of raw materials in a reactor at a bed temperature of 500 - 550 °C to obtain a liquid and performing distillation of the obtained liquid to make fractions. Further, the pyrolysis is performed in the presence of a catalyst. In addition, the solid by-product produced is a char that has high amount of essential nutrients like potassium and phosphorous which are essential for plants. The high calorific value gas produced during pyrolysis is captured separately and further used as a biofuel alternative.

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A COMPOSITION AND METHOD FOR THE PRODUCTION OF BIOFUEL FROM EDIBLE OIL REFINERY BY-PRODUCTS AND WASTES

FIELD OF THE INVENTION

The present invention relates generally to a field of biofuel production and in particular to a composition and method for the production of biofuel from edible oil refinery by-products and wastes.

BACKGROUND OF THE INVENTION

Energy in the form of fuel is the most common resource for development and increasing demand for energy now comes with the added need for sustainable development. The scarcity of known petroleum reserves is increasing social and economic pressures to develop renewable energy resources. Increasing awareness about the depletion of the fossil fuels such as petrol oil, coal and natural gas and related environmental issues have created a need to develop more efficient and sustainable energy sources and biofuels have emerged as an alternative. The most practicable manner to meet this growing energy demand is by making effective use of alternative fuels.

Edible Oils Refining is required for crude vegetable oils & fats or animal oils & fats to be used for cooking and frying food products. To improve the basic functionality and to remove the impurities, crude edible oils are refined either through a process of chemical refining (by using chemicals like caustic soda) or physical refining (by use of high temperature) to form edible oil and by-products. The by-products produced during the process are inedible, some are further processed and others are disposed-off, as they are not seen as commercially valuable. Some of these major relevant By-products that are disposed off are spent clay from vegetable oils bleaching, spent wax of sunflower oil and rice-bran oil, soap stock of soybean oil, sunflower oil, peanut oil, mustard oil, safflower oil, palm oil, rice bran oil, cotton seed oil etc. and chemical/ biological sludge

from the Effluent Treatment Plant (ETP).

There have been a number of methods provided for production of bio fuel from vegetable oils & animal fats. Few of them have been discussed below:

US20160024394A1 relates to a method for producing a fuel or solvent comprising a branched alkane, a branched alkene, or a combination thereof comprising heating a fatty acid in the presence of one or more alkenes to produce fuel. Further, the fatty acid resources include vegetable oil, animal fats, lipids derived from bio solids, spent cooking oil, lipids, phospholipids, soapstock or other sources of triglycerides, diglycerides or monoglycerides.

US8100990B2 provides a method of integrated biomass fast pyrolysis and fractionation. The method further comprises production of agglomerated biochar from one or more added binders such as lignosulfonates, vegetable oil, water, whole bio-oil, bio-oil fractions, biomass, clay, bitumen, coal and any combinations thereof.

US8317883B1 provides bio-oil produced from mustard family seeds. Further, the bio-oil is produced by a method involving pyrolyzing the feedstock to produce bio-oil, bio-char and non-condensable gases, removing the bio-char from the bio-oil, condensing the bio-oil and precipitating the bio-oil.

WO2014209973A1 provides a catalyst useful for biomass pyrolysis and bio-oil upgrading. Further, the catalysts are especially useful for microwave- and induction-heating based pyrolysis of biomass, solid waste and other carbon containing materials into bio-oil.

Most of the commercial biodiesel is produced from plant oils using homogeneous alkali catalysts such as sodium or potassium hydroxides, carbonates or alkoxides, which are very sensitive to the presence of water, free fatty acids and require more amount of carbinol. Since, the alkali catalysts must be neutralized, giving rise to wastewaters,

they cannot be reutilized and glycerol is obtained as an aqueous solution of relatively low purity.

The aforesaid documents and similar disclosures which talk about several biofuel or bio-oil production methods involving spent vegetable oil or catalyst comprises of number of shortcomings and drawbacks such as, but not limited to, lower efficiency, high cost, low calorific value and few of them are environmentally hazardous or create a large effluent stream.

Accordingly, there remains a need in the prior art for a method of producing biofuel from the waste materials, by-products from edible oil industry at low cost, which is self-sustaining, efficient and which has high calorific value and which generates no added environmental stress.

OBJECT OF THE INVENTION

An object of the present invention is to provide a composition of biofuel that can be prepared from the edible oil refinery waste and by-products.

Another object of the present invention is to provide a method for the production of biofuel from processing edible oil waste and by-products that requires no external energy source to manufacture after process initiation.

Another object of the present invention is to provide a method for the production of biofuel which possess properties similar to that of High Speed Diesel (HSD).

Another object of the present invention is to provide a composition of biofuel that can be put to various fuel related uses, such as a direct fuel for use in vehicles, a component of a biofuel or blend, a fuel additive, a fuel supplement, as fuel for generation of power and for use in boilers, heat generators, furnaces etc.

Another object of the present invention is the generation of a high-

energy gaseous product that has energy properties similar to natural gas or Liquefied Petroleum Gas (LPG).

Another object of this invention is the production of a solid by-product, such as biochar, which is high in essential nutrients required by plants such as potassium and phosphorous.

SUMMARY OF THE INVENTION

The present invention is described hereinafter by various embodiments. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiment set forth herein. Rather, the embodiment is provided so that this disclosure will be thorough and complete and will fully convey the scope of the invention to those skilled in the art.

In accordance with an embodiment of the present invention, a method for the production of biofuel is disclosed. The method comprises steps of, but not limited to, providing a plurality of raw materials from edible oil refinery, performing pyrolysis of the plurality of raw materials in a reactor at a bed temperature of 500 - 550 °C to obtain vapors or a liquid on rapid cooling of the vapors by performing step wise cooling of the vapors to obtain liquid fractions of different properties or distillation of the obtained liquid from rapid cooling of the vapors to make fractions.

In accordance with an embodiment of the present invention, the pyrolysis is performed in the presence of a catalyst which is derived from the plurality of raw materials.

In accordance with an embodiment of the present invention, the edible oil is selected from, but not limited to, a group comprising, sunflower oil, rice bran oil, soybean oil, peanut oil, palm oil, mustard oil and other soft oils.

In accordance with an embodiment of the present invention, the other soft oils are selected from, but not limited to, a group comprising, rapeseed oil, sesame oil, safflower oil, canola oil, mustard oil and corn oil.

In accordance with an embodiment of the present invention, the plurality of raw materials are obtained from, but not limited to, edible oil refinery by-products, co-products and effluent.

In accordance with an embodiment of the present invention, the plurality of raw materials are selected from, but not limited to, a group comprising, spent clay, soap stock, spent wax and Effluent Treatment Plant (ETP) Waste.

In accordance with an embodiment of the present invention, the pyrolysis produces products selected from, but not limited to, a group comprising, a high calorific value liquid, a high calorific value gas, a solid by-product. Further, high calorific value gas produced during pyrolysis is further used in the process itself to provide the heat energy for pyrolysis.

In accordance with an embodiment of the present invention, the high calorific value gas produced during pyrolysis is further recycled in the process or can be sold as a fuel gas which has more than 3 times the calorific value of methane.

In accordance with an embodiment of the present invention, the solid by-product is char, which on oxidation can be reused in the Vegetable oil refinery as a Bleaching clay or as an ingredient for de waxing.

In accordance with an embodiment of the present invention, the step of providing comprising the steps of drying the plurality of raw materials by using a double drum dryer and delivering the dried raw material in the reactor for pyrolysis.

In accordance with an embodiment of the present invention, the heat energy produced during the step wise cooling of the vapors is used

as input energy for the step of providing. Preferably, the heat energy is used to generate steam which eventually heats the double drum dryer.

In accordance with an embodiment of the present invention, a biofuel composition comprises an olefins present in a range of, but not limited to, 18%- 20% by weight, a paraffin present in a range of, but not limited to, 67.5% - 69.5% by weight, an aromatic compound present in a range of, but not limited to, 1%-1.5% by weight, an aqueous phase present in a range of, but not limited to, 0.5%-1% by weight, a residual oil coke present in a range of, but not limited to, 8%-10% by weight and other compounds present in a range of, but not limited to, 5%- 7% by weight.

In accordance with an embodiment of the present invention, the composition has gross calorific value in a range of, but not limited to, 10,000 Kcal/Kg – 10,810 Kcal/Kg.

In accordance with an embodiment of the present invention, the composition has density in a range of, but not limited to, 0.825 g/ml -0.90 g/ml.

In accordance with an embodiment of the present invention, the composition has a cetane index in the range of 46 – 60.

In accordance with an embodiment of the present invention, the composition has Sulphur content in an amount of < 10 ppm.

BRIEF DESCRIPTION OF THE DRAWINGS

So that the manner in which the above recited features of the present invention can be understood in detail, a more particular to the description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawing. It is to be noted, however, that the appended drawing illustrates only typical embodiments of this invention and are therefore not to be

considered limiting of its scope, the invention may admit to other equally effective embodiments.

These and other features, benefits and advantages of the present invention will become apparent by reference to the following text figure, with like reference numbers referring to like structures across the views, wherein:

Fig. 1 is a flow chart illustrating a method for the preparation of biofuel composition, in accordance with an embodiment of the present invention;

Fig. 2 illustrates a heavy-duty multi-cylinder engine setup, for testing of the heavy fraction of the biofuel, in accordance with an embodiment of the present invention;

Fig. 3 illustrates a graph showing comparison of dynamic fuel injection timings of diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends (25%, 50%, 75% and 100%) at varying loads, with a biofuel of Cetane Index 46, in accordance with an embodiment of the present invention;

Fig. 4 illustrates a graph showing comparison of ignition delay between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends at varying loads, with the biofuel of Cetane Index 46, in accordance with an embodiment of the present invention;

Fig. 5A illustrates a graph showing comparison of cylinder pressure histories at 20% between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 5B illustrates a graph showing comparison of cylinder pressure histories at 80% load between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends, with the heavy fraction biofuel of

cetane index 46, in accordance with an embodiment of the present invention;

Fig. 5C illustrates a graph showing comparison of peak pressures at varying loads between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 6 illustrates a graph showing comparison of maximum rate of pressure rise between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends at varying loads, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 7A illustrates a graph showing comparison of heat release rates at 20% load at varying loads between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends, with a heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 7B illustrates a graph showing comparison of heat release rates at 80% load at varying loads between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends, with a heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 7C illustrates a graph showing comparison of combustion duration at varying loads between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 8A illustrates a graph showing comparison of Brake Specific Fuel Consumption (BSFC) of the engine with diesel, neat heavy fraction biofuels and heavy fraction biofuels-diesel blends at varying loads, with the heavy fraction biofuel of cetane index 46, in accordance with an

embodiment of the present invention;

Fig. 8B illustrates a graph showing comparison of Brake Specific Energy Consumption (BSEC) of the engine with diesel, neat heavy fraction biofuels and heavy fraction biofuels-diesel blends at varying loads, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 8C illustrates a graph showing comparison of brake thermal efficiency of the engine with diesel, neat heavy fraction biofuels and heavy fraction biofuels-diesel blends at varying loads, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 9 illustrates a graph showing comparison of NO_x emissions with diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends are compared at varying loads, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 10 illustrates a graph showing comparison of exhaust smoke emissions with diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends at varying loads, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention;

Fig. 11 illustrates a graph showing comparison of unburned hydrocarbon (HC) emissions between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention; and

Fig. 12 illustrates a graph showing comparison of Carbon Monoxide (CO) emissions with diesel, neat heavy fraction biofuel, heavy fraction biofuel-diesel blends, with the heavy fraction biofuel of cetane index 46, in accordance with an embodiment of the present invention; and

Fig. 13 illustrates the process of drying of wet stock generated from edible oil refinery in form of waste using the double drum dryer in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

While the present invention is described herein by way of example using embodiments and illustrative drawings, those skilled in the art will recognize that the invention is not limited to the embodiments of drawing or drawings described, and are not intended to represent the scale of the various components. Further, some components that may form a part of the invention may not be illustrated in certain figures, for ease of illustration, and such omissions do not limit the embodiments outlined in any way. It should be understood that the drawings and detailed description thereto are not intended to limit the invention to the particular form disclosed, but on the contrary, the invention is to cover all modifications, equivalents, and alternatives falling within the scope of the present invention as defined by the appended claim. As used throughout this description, the word "may" is used in a permissive sense (i.e. meaning having the potential to), rather than the mandatory sense, (i.e. meaning must). Further, the words "a" or "an" mean "at least one" and the word "plurality" means "one or more" unless otherwise mentioned. Furthermore, the terminology and phraseology used herein is solely used for descriptive purposes and should not be construed as limiting in scope. Language such as "including," "comprising," "having," "containing," or "involving," and variations thereof, is intended to be broad and encompass the subject matter listed thereafter, equivalents, and additional subject matter not recited, and is not intended to exclude other additives, components, integers or steps. Likewise, the term "comprising" is considered synonymous with the terms "including" or "containing" for applicable legal purposes. Any discussion of documents, acts, materials, devices, articles and the like is included in the specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any or all of these matters form part of the

prior art base or were common general knowledge in the field relevant to the present invention.

In this disclosure, whenever a composition or an element or a group of elements is preceded with the transitional phrase "comprising", it is understood that we also contemplate the same composition, element or group of elements with transitional phrases "consisting of", "consisting", "selected from the group of consisting of", "including", or "is" preceding the recitation of the composition, element or group of elements and vice versa.

The present invention is described hereinafter by various embodiments with reference to the accompanying drawing, wherein reference numerals used in the accompanying drawing correspond to the like elements throughout the description. This invention may, however, be embodied in many different forms and should not be construed as limited to the embodiment set forth herein. Rather, the embodiment is provided so that this disclosure will be thorough and complete and will fully convey the scope of the invention to those skilled in the art. In the following detailed description, numeric values and ranges are provided for various objects of the implementations described. These values and ranges are to be treated as examples only, and are not intended to limit the scope of the claims. In addition, a number of materials are identified as suitable for various facets of the implementations. These materials are to be treated as exemplary, and are not intended to limit the scope of the invention.

In accordance with an embodiment of the present invention, a composition for the preparation of a biofuel from edible oil refinery waste and by-products comprises olefins present in a range of, but not limited to, 18%-20%, paraffin present in a range of, but not limited to, 63%-70%, aromatic compounds present in a range of, but not limited to, 1%-1.5%, aqueous phase present in a range of, but not limited to, 0.5%-1%, others present in a range of, but not limited to, 9.50%-11.50% and coke residual oil present in a range of, but not limited to, 8%-10%.

The amount of aromatic compound is about 1.05% approximately,

and consequently have even lower percentage of Polycyclic Aromatic Hydrocarbon (PAH) in the final biofuel composition, much lower than the 10% limit of Polycyclic Aromatic Hydrocarbon (PAH) allowed in High Speed Diesel (HSD). Since, Polycyclic Aromatic Hydrocarbon (PAH) are suspected carcinogens, such an ultra-low value in this biofuel will make the use of biofuel composition safe and will further mitigate health and environmental risks. The composition possesses fuel efficiency similar to that of diesel oil.

In accordance with an embodiment of the present invention, the biofuel of present invention can replace diesel either in pure form or in blended form as biofuel-diesel blend. In any of the form there is no significant changes in the engine combustion and performance. Also, the exhaust smoke emissions are reduced as from use of High Speed Diesel (HSD). As, the Sulphur content is less than 10 ppm, the SO_x emissions are lower than even the ones specified for Bharat IV HSD.

Referring to the drawings, the invention will now be described in more detail. Figure 1 illustrates method for the production of biofuel from edible oil refinery waste and by-products, in accordance with an embodiment of the present invention.

At step 102, a plurality of raw materials are provided from edible oil refinery waste and by-products. Whereas, the edible oil is selected from a group comprising, sunflower oil, rice bran oil, soybean oil, peanut oil, palm oil, mustard oil and other soft oils. Further, the other soft oils are selected from a group comprising, rapeseed oil, sesame oil, safflower oil, canola oil, mustard oil and corn oil. Further, the plurality of raw materials are obtained from edible oil refinery waste, by-products and effluent.

In accordance with an embodiment of the present invention, the plurality of raw materials are selected from a group comprising, spent clay, soap stock and spent wax and Effluent Treatment Plant (ETP) waste. The spent wax and spent clay inherently has clay that acts as a catalyst. Additionally, some lime at 0.1% of feed may be added to keep acidity of

the final product low. Whereas, soap stock is dried at low moisture level prior to further processing for the production of biofuel. Additionally, an external catalyst like Bentonite or HZSM – 5 is added *in-situ*.

In accordance with an embodiment of the present invention, the step of providing (102) comprising the steps of drying the plurality of raw materials by using a double drum dryer and delivering the dried raw material in the reactor for pyrolysis. Preferably, the raw material is soap stock.

At step 104, pyrolysis is performed on the plurality of raw materials in a reactor at a bed temperature in the range of 500°C - 550°C to obtain vapors or a liquid. For the step of pyrolysis there are critical features such as presence of the right catalyst and process conditions like feed rate, bed temperature, temperature of cooling water etc. Further, the pyrolysis produces products selected from a group comprising, a high calorific value liquid, a high calorific value gas and a solid by-product. After the pyrolysis, a vapor temperature in the range of 375°C - 390°C is achieved. Subsequently, the feeding rate is maintained at a ratio of Kgs/hr of feed to volume of the reactor at 0.06 - 0.2.

In accordance with the embodiment of the present invention, a liquid is recovered from the pyrolysis process before distillation process by having a series of condensers for the pyrolysis vapors and cooling them selectively to obtain the fractions.

The obtained liquid may be directly used in boilers, furnaces and other heat generating equipment to replace High Speed Diesel (HSD) or Light Diesel Oil (LDO) as it gives the same heat and energy efficiencies with reduced smoke and particulate emissions.

In accordance with an embodiment of the present invention, wherein the step of performing (104) further comprising preforming step wise cooling of the vapors to obtain liquid fractions of different properties or distillation of the obtained liquid from rapid cooling of the vapors to

make fractions. Preferably, the heat energy produced during the step wise cooling of the vapors is used as input energy for the step of providing (102).

At step 106, distillation of the obtained vapors or liquid is performed to obtain fractions. Further, the critical parameters involved in distillation are the initial and final temperatures of the fraction cut taken to form a liquid component. Further, this liquid component may be distilled to obtain a High-Speed Diesel (HSD) like fuel to be used in automobiles.

In accordance with an embodiment of the present invention, the resulting liquid from pyrolysis may be passed through a straight path distillation up to a temperature of 190°C and heavy fractions of temperature between 191°C and 390°C. Further, this liquid component may be distilled to obtain a High-Speed Diesel (HSD) like fuel to be used in automobiles.

In accordance with an embodiment of the present invention, the high calorific value gas produced during pyrolysis is further recycled in the process to provide heat needed for the process. Additionally, the high calorific value gas produced during pyrolysis may be separated and further used as a biofuel alternative to natural gas or Liquefied petroleum gas (LPG) as it has equivalent calorific values.

As shown in figure 13, in accordance with the embodiment of present invention, the raw wet stock as produced in the refining of edible oil accumulated in the tank (1302) and is transferred as required to the crutcher (1304), where it is conditioned by the application of steam to the steam jacket (1306) or by the steam coils (1308) to attain optimum fluid character. Agitation is supplied by the motor-driven agitator (1310) to assure a homogeneous mixture. Catalyst is also added, if required. The raw stock as transferred to the soap crutcher (1304) normally has a moisture content in the range of 35% to 45%.

The stock is transferred by a transfer pump to a drum dryer, where

it continuously accumulates in a pool between two rolls (1312) and (1314). The rolls (1312) and (1314) are driven by a drive so as to move inwardly in the direction of the arrows and are adjusted for clearance so as to permit a thin layer of stock to be deposited on each roll.

Steam is continuously introduced to the rolls through the line (1316). The steam condensate is continuously withdrawn from the rolls by the dip pipes (1344) through a rotating joint on the opposite end of the drum. As the rolls rotate, moisture is removed from the film of stock on each roll so that it becomes a semi-solid by the time it reaches the knife (1318) imposed near the outer upper portion of each roll. The knife edge separates the layer of stock from the roll surface in a substantially continuous sheet. Moisture removed on the roll is exhausted to the atmosphere by means of a fan connected to the hood (1320) immediately above the double drum dryer.

Room air is introduced by blower (1322) through the line (1324) into the top portion of a cooling header (1326) having ports (1328) in its upper side so as to lift the dried stock sheet from the perforated cooling header surfaces and convey the sheet from the knife blade edge. Refrigerated air is introduced into the bottom section of the cooling header and discharged through the perforations (1330) in the outer side thereof to make the sheet prior to its introduction to the screw conveyor (1332). The air flows from an air cooler (1324). It is also preferred to introduce an added quantity of refrigerated air through the outlets (1334) into the screw conveyors to further cool the stock sheet and to dehumidify its surrounding air. If desired, the ground stock may be combined with a conditioning agent from the storage tank (1336), from which it is discharged through feeder (1338), the combination being formed in a paddle mixer (1340). From the mixer (1340), the finished-product goes to a surge bin (1342) and appropriate conveying and packaging equipment for packaging the product for use.

Hereinafter, non-limiting examples of the present invention will be

provided for more detailed explanation which is not meant to limit the scope of the invention in any manner.

EXPERIMENTS

1. The comparison of the values between High Speed Diesel (HSD), currently available biodiesel in the market and the heavy fraction of the biofuel as disclosed in present invention is provided in table 1.

Specification	HSD	Biodiesel	Biofuel
Ash Max (% Mass)	0.01		0.01
Carbon Residue (% mass)	0.3	0.05	< 0.5
Cetane Number (min)	48	51	NA
Cetane Index (min)	46		46 - 60
Flash Point Min (Deg C)	35	120	38
Kinematic Viscosity @ 40 Deg C in CST	2 - 4.5	2.5 - 6	2.6 - 4.8
Density at 15 Deg C (Kg/m ³)	820 - 845	860 - 900	825 - 860
Total Sulfur max (mg/kg)	50	50 Max	<10
Cold Filter plugging point Summer (Deg C)	18		
Cold Filter plugging point Winter (Deg C)	6		
water content max (mg/Kg)	200	500	250
Calorific Value (Kcal/Kg)	10800	9000	10000- 10810
Ester (% mass) min		> 96	
Total Contaminants	24	24	
Copper Strip Corrosion	Max 1	Max 3	1
Sediment by Mass			

Pour Point	5	15	9
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Table 1- comparison of the values between High Speed Diesel (HSD), currently available biodiesel in the market and the heavy fraction of the biofuel as disclosed in present invention

2. Experimental setup for Test Engine

A heavy-duty multi cylinder engine was used for the engine test as shown in figure 2. The heavy-duty multi cylinder engine was connected further with an eddy current dynamometer (212) to act as a load absorber and provide a quick load change rate for rapid load settling. Subsequently, the eddy current dynamometer (212) was provided with a water inlet (230) and water outlet (231) supported by a thermocouple. The eddy current dynamometer was then connected with a load cell (210) and one dynamometer controller (214). Consequently, the load cell (210) provides the thermocouple signals to the dynamometer controller (214). An air supply (228) provided, which was further configured to attach with the air filter (202), air flow meter (204) and surge tank (206) respectively. From surge tank (206) it was then attached with the heavy-duty multi cylinder engine (208) and controlled by a thermocouple (229). The surge tank (206) is provided to control the sudden rise in the pressure of the liquid flow. One end of the heavy-duty multi cylinder engine (208) was connected with an exhaust (224) that comprises a valve system (226) adapted to dispense the exhaust gases. The exhaust (224) was further connected with an exhaust gas analyzer (222) to measure the combustion rate.

Uncooled piezo-electric type 6055 sensors (216) having a pressure-measuring range of 250 bar were also connected with heavy-duty multi cylinder engine (208) for measuring in-cylinder gas pressures. The sensitivity of the pressure sensor ranges between $\pm 0.5\%$ over a temperature range of 200 ± 50 °C.

In the foregoing experiments the following denotations indicates:

- Diesel – 100% High Speed diesel (HSD) available in market

- B25 – 25% heavy fraction biofuel as disclosed in present invention and 75% HSD
- B50 – 50% heavy fraction biofuel as disclosed in present invention and 50% HSD
- B75 – 75% heavy fraction biofuel as disclosed in present invention and 25% HSD
- B100 – 100% heavy fraction biofuel as disclosed in present invention

a) Fuel Injection and Ignition

A comparison of dynamic fuel injection timings of Diesel, B25, B50, B75 and B100 at varying loads represented by Brake Mean Effective Pressure (BMEP) are shown in figure 3. The dynamic start of fuel injection timings was deduced from the fuel line pressure history by considering the crank angle at which the injector nozzle opening pressure of 230 bar was reached.

A comparison of ignition delay between Diesel, B25, B50, B75 and B100 at varying loads are shown in figure 4. The ignition delay was taken as the time elapse between start of fuel injection and start of combustion (taken as the slope change over point in the first derivative of cylinder pressure versus crank angle plot).

b) Combustion

The in-cylinder gas pressure history is a cardiogram of engine combustion analysis from which various combustion parameters are deduced such as heat release rate, peak cylinder pressure, maximum rate of pressure rises and duration of combustion. A comparison of cylinder pressure histories at 20% and 80% load and peak pressures at varying loads between Diesel, B25, B50, B75 and B100 at varying loads are shown in figures 5A, 5B and 5C.

c) A comparison of maximum rate of pressure rise between diesel, neat

heavy fraction biofuel and heavy fraction biofuel-diesel blends:

A comparison of maximum rate of pressure rise between Diesel, B25, B50, B75 and B100 at varying loads are presented in figure 6. The maximum rate of pressure rise is an indicator of combustion noise wherein a very high value could lead to engine damage.

d) Comparison of heat release rates and combustion duration:

A comparison of heat release rates at 20% and 80% loads and combustion duration at varying loads between Diesel, B25, B50, B75 and B100 as shown in figure 7A, 7B and 7C. The heat release rates are obtained from the cylinder pressure histories by applying first law thermodynamics for the closed part of engine cycle.

e) Engine Performance

The engine performance is evaluated in terms of Brake Specific Fuel Consumption (BSFC), Brake Specific Energy Consumption (BSEC) and brake thermal efficiency. The BSFC defined as the total fuel consumed by the engine to produce unit brake power output is evaluated on mass basis and thus, is an indicator of engine fuel economy. The BSEC is evaluated on energy basis, which is defined as the ratio of total energy consumed by the engine to the brake power output. The engine brake thermal efficiency is a measure of ability of the engine to convert fuel chemical energy into brake power output. A comparison of BSFC, BSEC and brake thermal efficiency of the engine with Diesel, B25, B50, B75 and B100 at varying loads is shown in figure 8A, 8B and 8C.

f) Engine Exhaust Emissions

The regulated emissions from diesel engine, viz. oxides of nitrogen (NO_x), smoke, carbon monoxide (CO) and unburned hydrocarbon (HC) are analyzed to examine the emission reduction potential with the heavy fraction biofuel of the present invention. The NO_x emissions with Diesel, B25, B50, B75 and B100 are compared at varying loads in figure 9.

The exhaust smoke emissions with Diesel, B25, B50, B75 and B100 at varying loads are compared in figure 10.

The smoke emissions are relatively more dependent on the extent of fuel-air mixing and the magnitude of heat release rates during the diffusion phase combustion. The smoke emissions with both the fuels remain considerably lower at all the loads except at full load. The lower smoke emissions with all the fuels at part loads could be attributed to turbocharged operation, which increases oxygen availability. The differences in smoke emissions between diesel and heavy fraction biofuel are not significant at part load conditions, however, at higher loads, the smoke emissions are reduced with neat heavy fraction biofuel and heavy fraction biofuel-diesel blends. The lower smoke emissions with heavy fraction biofuel signify its better mixing characteristics as compared to diesel.

A comparison of unburned hydrocarbon (HC) emissions between Diesel, B25, B50, B75 and B100 is shown in figure 11. The HC emissions are products of incomplete combustion, which are found to increase with less oxygen availability, crevice flow and flame quenching mechanisms. A higher HC emission signifies lower energy release during combustion and thereby, lowers combustion efficiency.

The carbon monoxide (CO) emissions with Diesel, B25, B50, B75 and B100 are compared at varying loads in Figure 12. The CO emissions are products of incomplete combustion, which are highly sensitive to changes in fuel-air equivalence ratio. A fuel-rich mixture increases the tendency of CO formation. Further, the oxidation of CO requires higher temperatures and thus the changes in in-cylinder gas temperature influences CO emissions.

3. The bleaching properties of crude vegetable oil with New clay and with recycled clay from the pyrolysis process.

Sr.No.		Palm Oil	Palm Oil
	Type of bleaching	New clay	Recycled clay from process

	earth				
	Type of bleaching earth	Before Bleachning	After bleaching	Before Bleachning	After bleaching
1	Oil Analysis				
1.1	FFA	4.83	5.16	4.83	4.65
1.2	PV				
1.3	COLOR	34	18	34	23
2	Heavy metals				
2.1	Ca	47.09	12.27	47.09	12.27
2.2	Mg	25.8	3	25.8	2.93
2.3	Fe	1.07	5.34	1.07	4.08
2.4	P	20.04	16.31	20.04	17.94
2.5	Cu	0.07	0.05	0.07	0.06
2.6	Mn	0.4	0.4	0.4	0.4
2.7	Al	0.31	3.39	0.31	1.64
2.8	Zn	1.93	0.52	1.93	0.41

Table 2 Given below are the bleaching properties of crude vegetable oil with New clay and with recycled clay from the pyrolysis process.

RESULTS

Experimental setup for Test Engine

a) Fuel Injection and Ignition

It was observed from the graph shown in figure 3 that there is no appreciable change in start of fuel injection timings with B25, B50, B75 and B100 as compared to diesel.

It was observed that the ignition delay decreases with an increase in load for all the fuels owing to higher in-cylinder temperatures. The ignition delay increases with an increase in proportion of biofuel i.e. lowest for Diesel and highest for B100 as shown in figure 4. The longer ignition delay with B100 is because a biofuel with a Cetane Index of 46 was used for this trial. If this number were to be raised, the ignition delay would be reduced to nil.

b) Combustion

It was observed that there are no significant changes in the pressure during expansion stroke and peak pressure between diesel, B25, B50, B75 and B100 signifying no appreciable drop in engine power output with heavy fraction biofuel as disclosed in present invention. However, there is a delayed start of combustion and a slight delay in the occurrence of peak pressure with B25, B50, B75 and B100 owing to their longer ignition delay due to the Cetane Index of 46 in heavy fraction biofuel used for this trial.

c) Comparison of maximum rate of pressure rise between diesel, B25, B50, B75 and B100

It was observed from figure 6 that the trends of maximum rate of pressure rise with changes in engine load are similar for diesel and B100 wherein it increases initially and then decreases. An increase in maximum rate of pressure rise during part load conditions could be attributed to premixed phase dominant combustion owing to longer ignition delay. As compared to diesel, the use of B25, B50, B75 and B100 result in somewhat higher rate of pressure rise, which could be primarily due to their longer ignition delay due to the Cetane Index of 46 as discussed earlier.

d) Comparison of heat release rates and combustion duration:

The combustion duration was taken as the time interval between 10% and 90% of cumulative heat release. There are two peaks in the heat release rates at 80% load owing to the presence of premixed as well as diffusion phase combustion, while combustion at 20% load is premixed dominant and thus showing only one peak. As compared to diesel, B25, B50, B75 and B100 show a delayed start of combustion and somewhat higher peak heat release rate. The occurrence of peak heat release rate is also delayed with B25, B50, B75 and B100 owing to a longer ignition delay compared to diesel due to cetane index of 46 which can be raised and even the small difference nullified. From figure 7B, it was observed that there were no appreciable changes in the combustion duration between

diesel, B25, B50, B75 and B100 except that the duration is longer with B100 at full load, which could be primarily due to a higher mass of fuel injection. The energy content of heavy fraction biofuel of as disclosed in present invention is slightly lower than that of diesel, which could lead to higher mass of fuel injection, especially at higher loads.

e) Engine Performance

It was observed from figure 8A that there is a slight increase in BSFC with an increase in heavy fraction biofuel proportion in diesel i.e. B25, B50, B75 and was highest for B100. These trends are attributed to the fact that the heating value (a measure of energy content) of heavy fraction biofuel is slightly lower than diesel and thus to maintain similar power output as that of diesel the fuel consumption need to be increased. However, from figure 8B and figure 8C it was observed that the changes in BSEC and brake thermal efficiency between diesel, B25, B50, B75 and B100 were insignificant. Thus, is concluded that the engine's ability to convert fuel's chemical energy into brake power output is similar with diesel and heavy fraction biofuel as disclosed in the present invention.

f) Engine Exhaust Emissions

The NO_x emissions were found to increase with an increase in cylinder gas temperatures, longer residence time and oxygen availability. The trends of NO_x emissions were similar with all the fuels, as shown in figure 9, wherein it increases with an increase in load owing to higher cylinder gas temperatures at higher loads. Although, the changes in NO_x emissions between diesel, B25, B50, B75 and B100 were insignificant at lower loads, there was a slight increase in NO_x emissions with B25, B50 and B75 at higher loads. These trends were due to the fact that the ignition delay was longer with B25, B50 and B75 leading to more intense premixed combustion, higher cylinder gas temperatures and thereby, higher NO_x emissions. This can be nullified by using a Bio fuel of higher cetane index than 46 used for this experiment.

The exhaust smoke emissions with diesel, B25, B50, B75 and B100 at varying loads were compared as shown in Fig. 10. The smoke emissions with both the fuels remain considerably lower at all the loads except at full load. The lower smoke emissions with all the fuels at part loads could be attributed to turbocharged operation that increases oxygen availability. The differences in smoke emissions between diesel and heavy fraction biofuel as disclosed in the present invention were not significant at part load conditions, however, at higher loads, the smoke emissions were reduced with B100 and B25, B50 & B75. The lower smoke emission with heavy fraction biofuel as disclosed in present invention signifies its better mixing characteristics as compared to diesel.

A comparison of unburned hydrocarbon (HC) emissions between diesel, B25, B50, B75 and B100 it was observed from figure 11, the HC emissions were well below 10 ppm with all the fuels primarily due to increased oxygen availability with turbocharged operation. The HC emissions with B25, B50, B75 and B100 were either comparable or slightly lower than that of diesel, however, the differences were not significant.

The carbon monoxide (CO) emissions with diesel, B25, B50, B75 and B100 were compared at varying loads in figure 12. It was observed that the trends of CO emissions with changes in engine load were similar with all the fuels. The CO emissions were higher at lower and higher loads due to lower in-cylinder gas temperatures and locally fuel-rich regions respectively. Although, the differences in CO emissions between diesel and heavy fraction biofuel as disclosed in present invention were not significant at intermediate load conditions, they were higher at lower and higher loads with heavy fraction biofuel.

Further, table 3, table 4, table 5, table 6 and table 7 shows the engine combustion, performance and emission data with diesel, B25, B50, B75 and B100.

BMEP (bar)	SOI (deg. CA aTDC)	SOC (deg. CA aTDC)	ID (deg. CA)	CD (deg. CA)	Pmax (bar)	Occurrence of Pmax (deg. CA)	(dp/dθ) max (bar/deg. CA)	BSFC (g/KW hr)	BSEC (kJ/k Whr)	BTE (%)	CO (% vol.)	HC (ppm hex)	NO (ppm)	Smoke (mg/m ³)
0.72	-10.4	0.9	11.3	11.7	62.7	5.1	7.15	625	2794 1	12.88	0.09	9	212	0.215
1.87	-10.7	-0.2	10.5	12.6	71.0	5.7	9.49	338	1510 2	23.84	0.06	8	490	0.485
3.87	-10.6	-0.2	10.4	13.3	81.5	6.2	11.77	252	1123 7	32.04	0.02	9	967	0.945
6.04	-10.4	-1.0	9.4	16.7	90.7	7.5	10.58	223	9954	36.17	0.02	10	130 3	2.065
7.51	-10.3	-2.0	8.3	21.1	98.7	8.5	9.21	211	9428	38.19	0.01	9	151 0	3.615
9.61	-9.9	-2.7	7.2	30.9	108.5	9.2	8.40	210	9383	38.37	0.05	7	148 9	18.145

Table 3: An Engine Combustion, Performance and Emission Data with Diesel

BME P (bar)	SOI (deg. CA aTDC)	SOC (deg. CA aTDC)	ID (deg. CA)	CD (deg. CA)	Pma x (bar)	Occur rence of Pmax (deg. CA)	(dp/dθ) max (bar/deg. CA)	BSFC (g/KW hr)	BSEC (kJ/kWh r)	BTE (%)	CO (% vol.)	HC (pp m hex)	NO (pp m)	Smoke (mg/m ³)
0.74	-10.5	0.9	11.4	11.5	63.1	5.1	6.69	643	28142	12.79	0.12	10	203	0.055
1.72	-10.8	0.3	11.1	11.3	70.0	5.8	10.01	368	16089	22.38	0.07	9	451	0.315
3.76	-10.8	0	10.8	12.7	82.4	5.1	12.99	257	11249	32.00	0.03	12	102 4	0.600
6.13	-10.6	-1.1	9.5	16.2	92.4	7.2	11.36	224	9790	36.77	0.02	13	149 9	1.460
7.56	-10.4	-1.9	8.5	20.4	99.8	8.4	9.41	217	9476	37.99	0.01	14	163 0	1.950
9.64	-9.6	-2.4	7.2	30.6	107. 8	8.8	8.68	214	9368	38.43	0.05	12	153 8	14.085

Table 4: An Engine Combustion, Performance and Emission Data with B25

BME P (bar)	SOI (deg. CA aTDC)	SOC (deg. CA aTDC)	ID (deg. CA)	CD (deg. CA)	Pmax (bar)	Occ urre nce of Pma x (deg. CA)	(dp/dθ) max (bar/deg. CA)	BSFC (g/kWh r)	BSEC (kJ/kWh r)	BTE (%)	CO (% vol.)	HC (pp m hex)	NO (pp m)	Smok e (mg/m 3)
0.85	-10.3	1.3	11.6	11.2	63.4	5.4	7.40	584	24906	14.45	0.13	5	209	0.210
1.91	-10.6	0.5	11.1	11.2	70.8	5.9	11.03	348	14817	24.30	0.08	3	488	0.265
3.92	-10.6	0.2	10.8	12.1	83.0	5.3	12.08	259	11034	32.63	0.03	5	104 9	0.365
5.84	-10.5	-0.7	9.8	15.1	91.2	7.5	10.62	231	9845	36.57	0.02	3	139 3	0.650
7.71	-10.3	-2.0	8.3	21.1	98.7	8.5	9.21	220	9381	38.38	0.02	4	163 1	1.600
9.63	-9.7	-2.2	7.5	29.6	108. 3	8.7	8.84	217	9262	38.87	0.05	0	155 8	10.45 5

Table 5: An Engine Combustion, Performance and Emission Data with B50

MEP (bar)	SOI (deg. CA aTDC)	SOC (deg. CA aTDC)	ID (deg. CA)	CD (deg. CA)	Pmax (bar)	Occur rence of Pmax (deg. CA)	(dp/dθ) max (bar/deg . CA)	BSFC (g/KWh r)	BSEC (kJ/kWh r)	BTE (%)	CO (% vol.)	HC (pp m hex)	NO (pp m)	Smok e (mg/m 3)
0.35	-10.3	2.3	12.6	10.4	59.1	6.5	5.39	1171	48830	7.37	0.14	11	104	0.150
1.76	-10.8	1.1	11.9	10.9	69.1	5.2	8.62	372	15509	23.21	0.07	13	436	0.240
3.98	-10.5	0.7	11.2	12.0	82.6	5.9	13.06	265	11050	32.58	0.01	14	109 2	0.260
5.64	-10.3	-0.2	10.1	15.7	90.2	6.9	12.37	237	9884	36.42	0	15	137 8	0.550
7.60	-9.9	-0.9	9.0	20.5	98.5	8.4	10.43	225	9386	38.35	0	15	167 5	1.215
9.52	-9.9	-1.7	8.2	30.4	106.9	8.9	8.49	222	9238	38.97	0.03	13	157 9	9.365

Table 6: An Engine Combustion, Performance and Emission Data with B75

BME P (bar)	SOI (deg. CA aTDC)	SOC (deg. CA aTDC)	ID (deg. CA)	CD (deg. CA)	Pma x (bar)	Occurr ence of Pmax (deg. CA)	(dp/dθ) max (bar/d eg. CA)	BSFC (g/KW hr)	BSEC (kJ/k W hr)	BTE (%)	CO (% vol.)	HC (pp m hex)	NO (ppm)	Smok e (mg/m 3)
0.76	-10.5	2.7	13.2	9.9	61.5	6.7	5.93	673	2720 5	13.23	0.18	11	135	0.350
1.90	-10.8	1.4	12.2	10.7	70.0	5.5	9.01	368	1487 9	24.19	0.10	7	423	0.355
3.66	-10.7	1.5	12.2	10.8	81.9	6.6	12.67	278	1122 0	32.09	0.04	5	972	0.315
6.12	-10.5	0.2	10.7	16.9	91.7	7.4	11.44	239	9657	37.28	0.02	4	1349	0.715
7.59	-10.2	-0.5	9.7	22.8	97.2	7.9	10.43	230	9295	38.73	0.02	1	1511	1.730
9.56	-9.7	-1.2	8.5	37.4	107. 5	9.3	9.80	228	9222	39.04	0.07	0	1488	15.30 0

Table 7: An Engine Combustion, Performance and Emission Data with B100

Conclusion

A composition of biofuel from edible oil refinery by-products and wastes has been successfully obtained. The experiment shows that the heavy fraction biofuel can replace diesel with B100 or B25, B50, B75 and that there are no significant changes in the engine combustion and performance, the exhaust smoke emissions were reduced. Bio oil yield was about 67% from Pyrolysis of Spent wax and the char yield was about 15% - 18% with the rest being the high calorific value gas, which could

replace natural gas and Liquefied Petroleum Gas (LPG) as it has similar calorific value. Heavy fraction biofuel yield after distillation is over 85% and the fuel properties of obtained, as disclosed in present invention, fraction are exactly in the range required for vehicular diesel. The Char thus obtained is rich in important nutrients like potassium and phosphorous which may be further used as a soil nutrient to improve crop yield and soil quality, as a precursor for extraction of silica or in the making of adsorbents to be used in water purification, removal of heavy metals etc.

Further, there are no appreciable change in the dynamic start of fuel injection timings with neat heavy fraction biofuel and heavy fraction biofuel-diesel blends compared to diesel. A small and insignificant ignition delay was observed, which increases as the heavy fraction biofuel proportion in the fuel increases. This can be addressed by increasing the cetane index of the fuel, which is within the embodiment of this Invention.

In addition, as compared to diesel, heavy fraction biofuel and heavy fraction biofuel-diesel blends show a delayed start of combustion, somewhat higher peak heat release rate with a delayed occurrence. There are no appreciable changes in the combustion duration between diesel, neat heavy fraction biofuel and heavy fraction biofuel-diesel blends. Moreover, the elemental analysis shows that the biofuel composition has very low Sulphur content of < 10 ppm that reduces environmental pollution.

The exemplary implementation described above is illustrated with specific structure, ingredients, and other characteristics, but the scope of the invention includes various other structures, ingredients, and characteristics. In addition, the composition and method as described above could be fabricated in various other ways and could include various other materials, to provide a biofuel.

Various modifications to these embodiments are apparent to those skilled in the art from the description and the accompanying drawings. The principles associated with the various embodiments described herein may

be applied to other embodiments. Therefore, the description is not intended to be limited to the embodiments shown along with the accompanying drawings but is to be provided broadest scope consistent with the principles and the novel and inventive features disclosed or suggested herein. Accordingly, the invention is anticipated to hold on to all other such alternatives, modifications, and variations that fall within the scope of the present invention and appended claims.

We Claim:

1. A method (100) for the production of biofuel, the method comprising the steps of:

providing (102) a plurality of raw materials from edible oil refinery;

performing (104) pyrolysis of the plurality of raw materials in a reactor at a bed temperature of 500 °C - 550 °C to obtain vapors or a liquid;

performing (106) distillation of the obtained vapors or liquid to make fractions;

wherein the pyrolysis is performed in the presence of a catalyst which is derived from the plurality of raw materials

2. The method as claimed in claim 1, wherein the edible oil is selected from a group comprising, sunflower oil, rice bran oil, soybean oil, peanut oil, palm oil, mustard oil and other soft oils.

3. The method as claimed in claim 1, wherein the other soft oils are selected from a group comprising, rapeseed oil, sesame oil, safflower oil, canola oil, mustard oil and corn oil.

4. The method as claimed in claim 1, wherein the plurality of raw materials are obtained from edible oil refinery by-products, co products, wastes and effluent.

5. The method as claimed in claim 1, wherein the plurality of raw materials are selected from a group comprising, spent clay, soap stock and spent wax and Effluent Treatment Plant (ETP) waste.

6. The method as claimed in claim 1, wherein the pyrolysis produces products selected from a group comprising, a high calorific value liquid, a high calorific value gas, a solid by-product.

7. The method as claimed in claim 1, wherein the high calorific value gas produced during pyrolysis is further recycled in the process.

8. The method as claimed in claim 1, wherein the solid by-product is char.

9. The method as claimed in claim 1, wherein the step of providing (102) comprising the steps of
drying the plurality of raw materials by using a double drum dryer;
and
delivering the dried raw material in the reactor for pyrolysis.

10. The method as claimed in claim 9, wherein the raw material is soap stock.

11. The method as claimed in claim 1, wherein the step of performing (104) further comprising preforming step wise cooling of the vapors to obtain liquid fractions of different properties or distillation of the obtained liquid from rapid cooling of the vapors to make fractions.

12. The method as claimed in claim 11, wherein the heat energy produced during the step wise cooling of the vapors is used as input energy for the step of providing (102).

13. A biofuel composition, the composition comprising:
an olefin presents in a range of 18%- 20% by weight;
a paraffin present in a range of 67.5% - 69.5% by weight;
an aromatic compound present in a range of 1.0%-1.5% by weight;
an aqueous phase present in a range of 0.5%-1% by weight;
a residual oil coke present in a range of 8%-10% by weight; and
other compounds present in a range of 5%- 7% by weight.

14. The composition as claimed in claim 13, wherein the composition has a calorific value in a range of 10000 Kcal/Kg - 10810 Kcal/Kg.

15. The composition as claimed in claim 13, wherein the composition has density in the range of 0.825 to 0.90 g/ml.

16. The composition as claimed in claim 13, wherein the composition has a cetane index in the range of 46 – 60.

17. The composition as claimed in claim 13, wherein the composition has Sulphur content in an amount of < 10 ppm.

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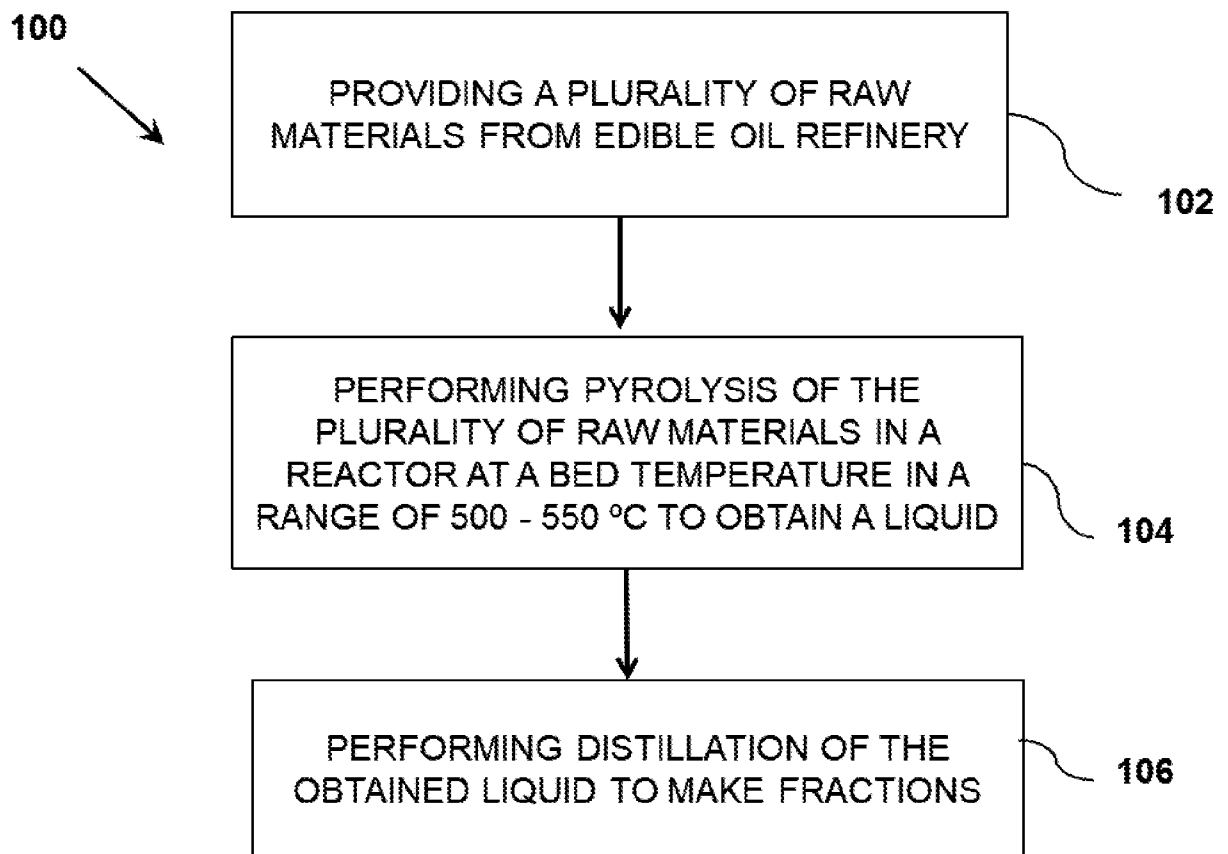


Fig.1

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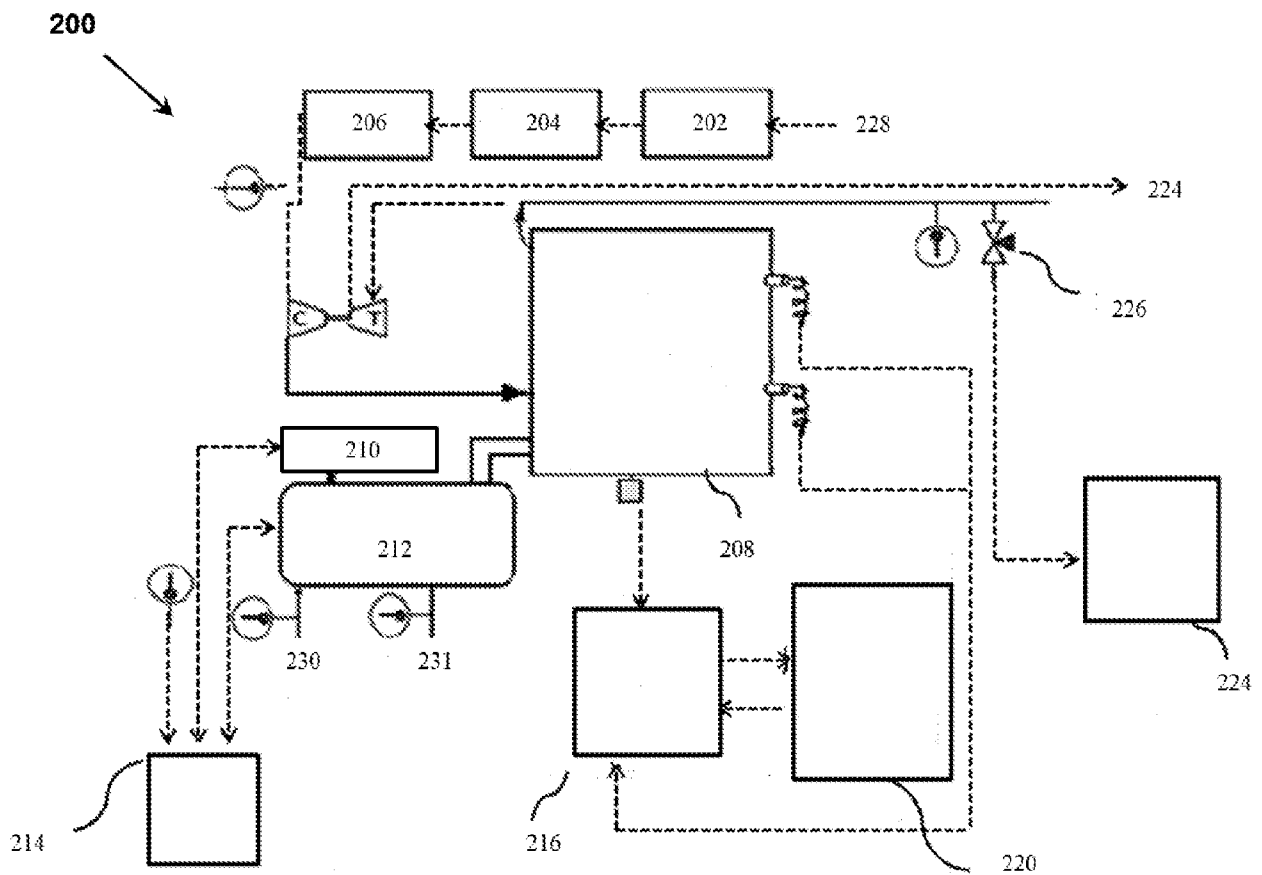


Fig. 2

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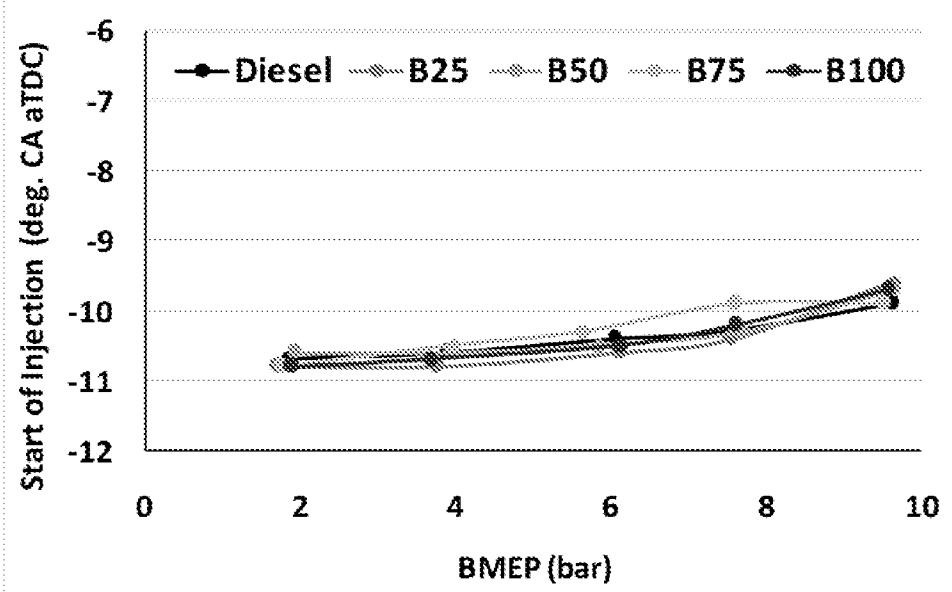


Fig. 3

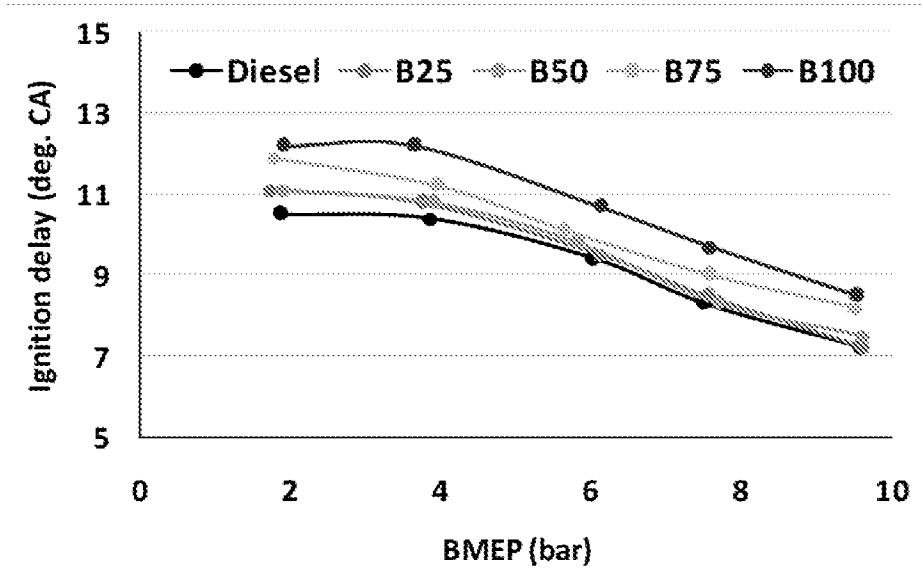


Fig. 4

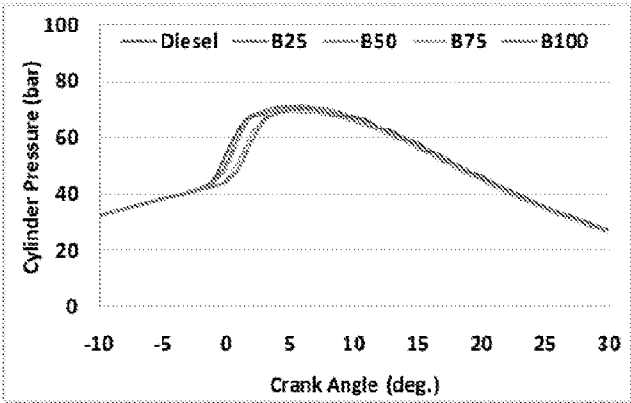


Fig. 5A

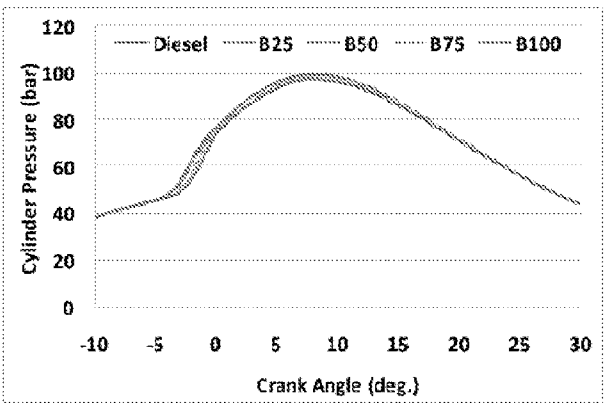


Fig. 5B

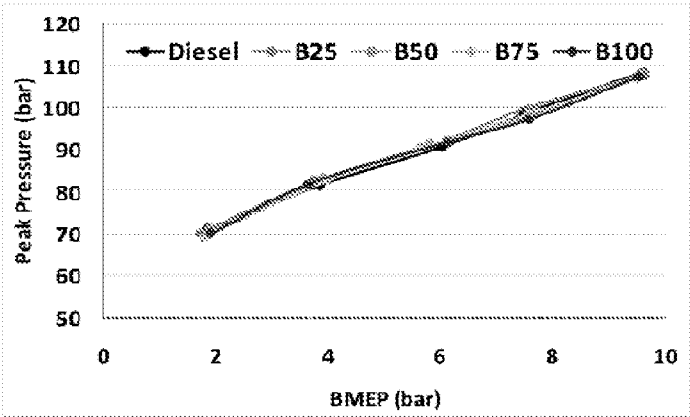


Fig. 5C

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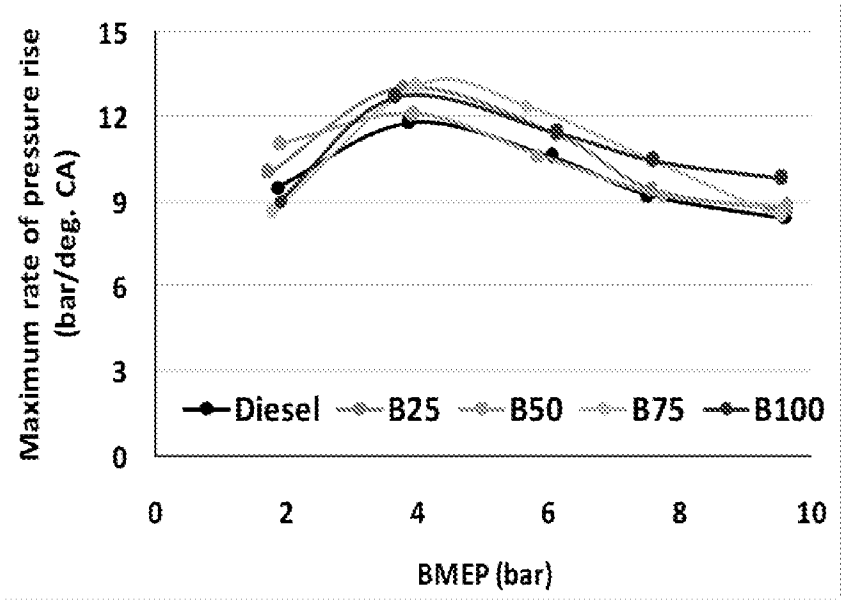


Fig. 6

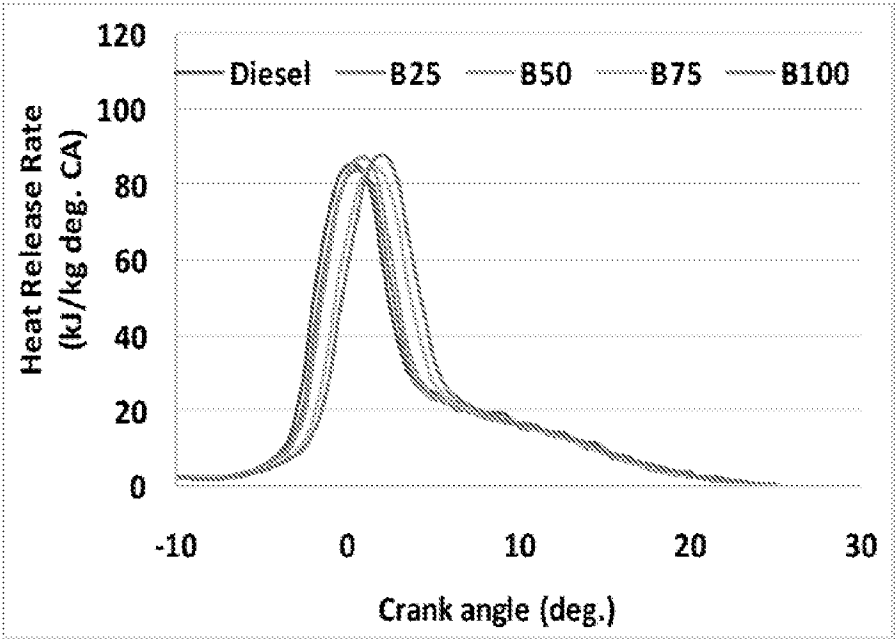


Fig. 7A

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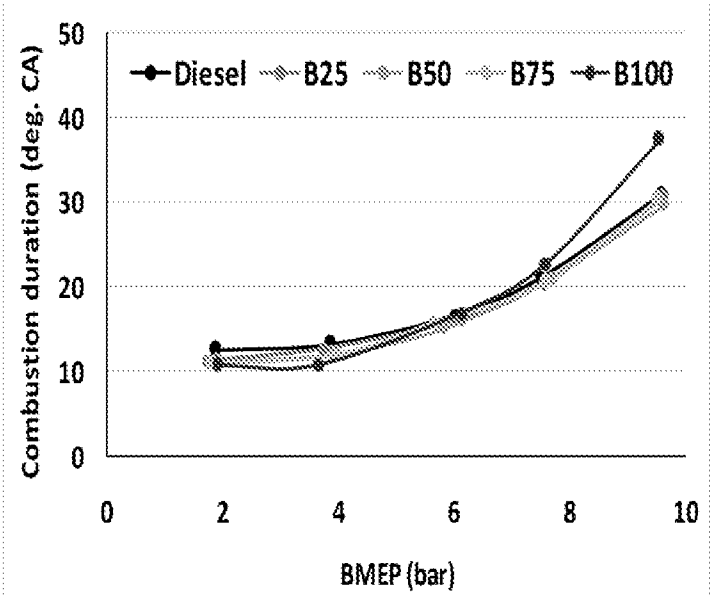


Fig. 7B

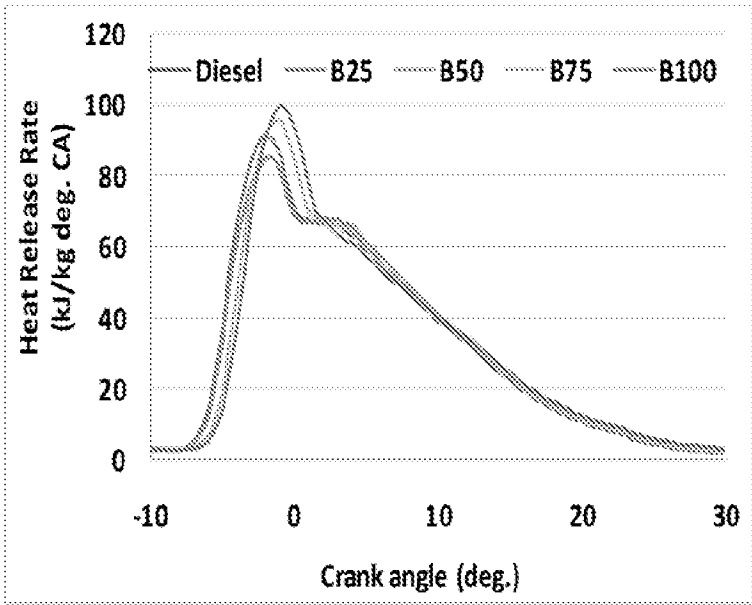


Fig. 7C

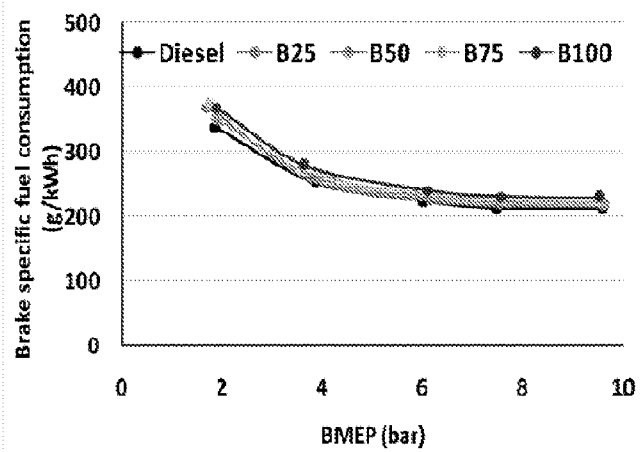


Fig. 8A

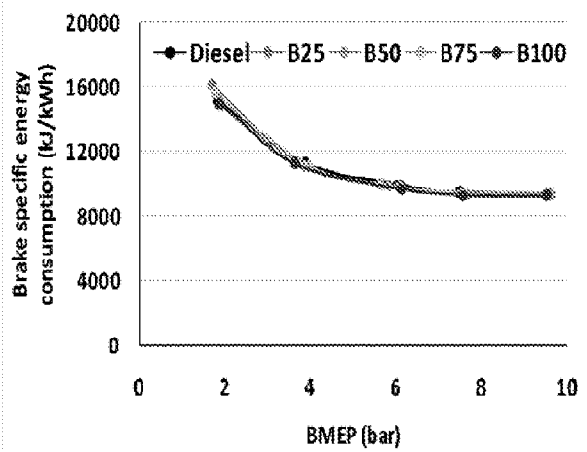


Fig. 8B

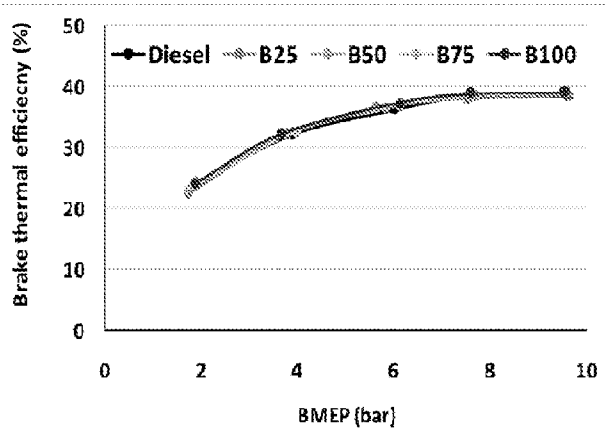


Fig.8C

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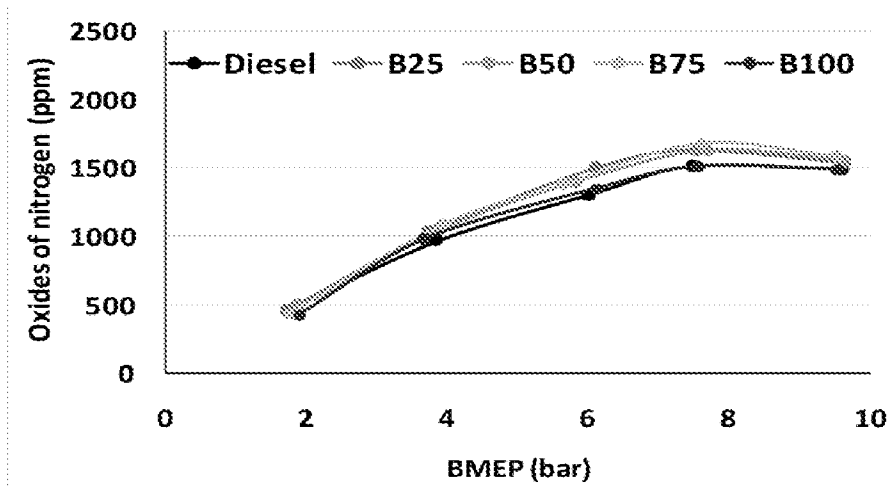


Fig. 9

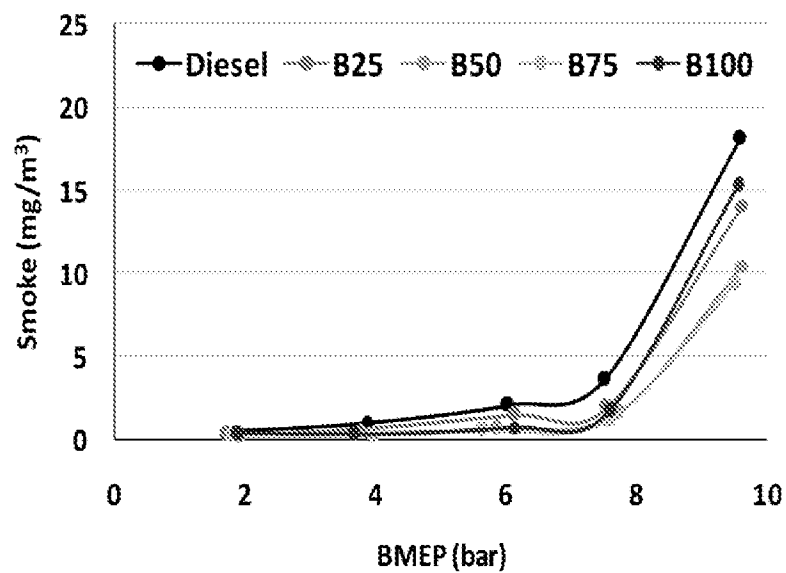


Fig. 10

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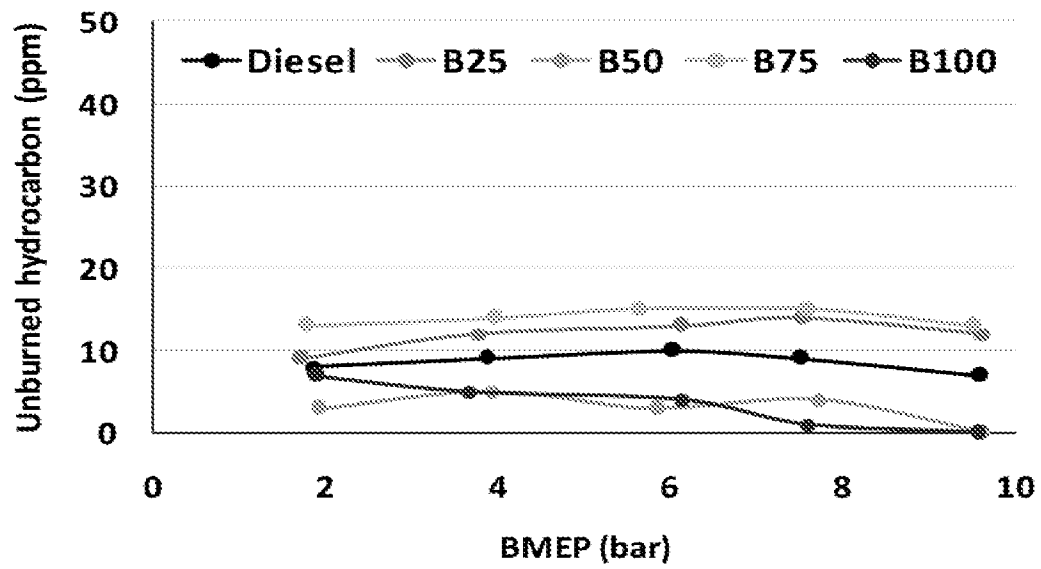


Fig. 11

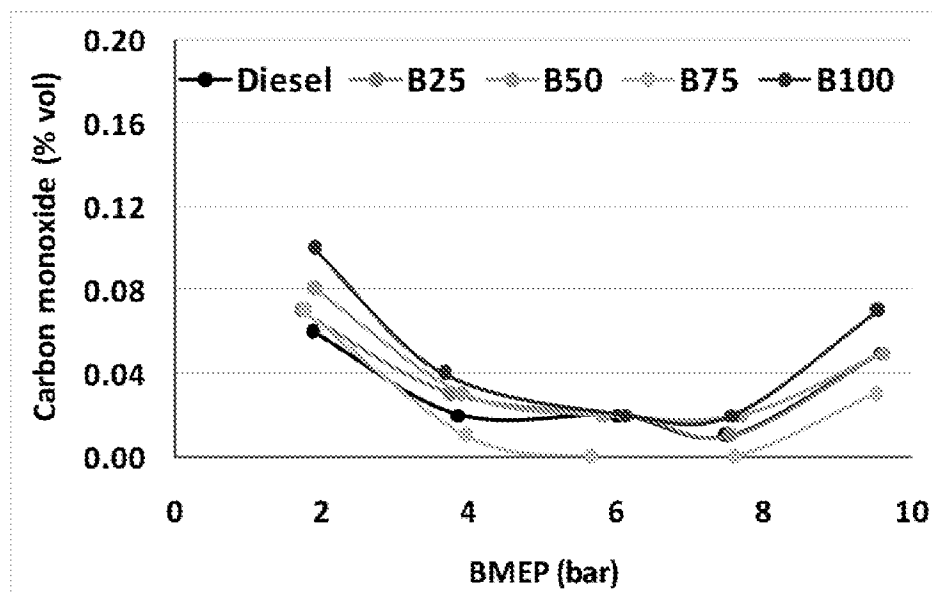


Fig. 12

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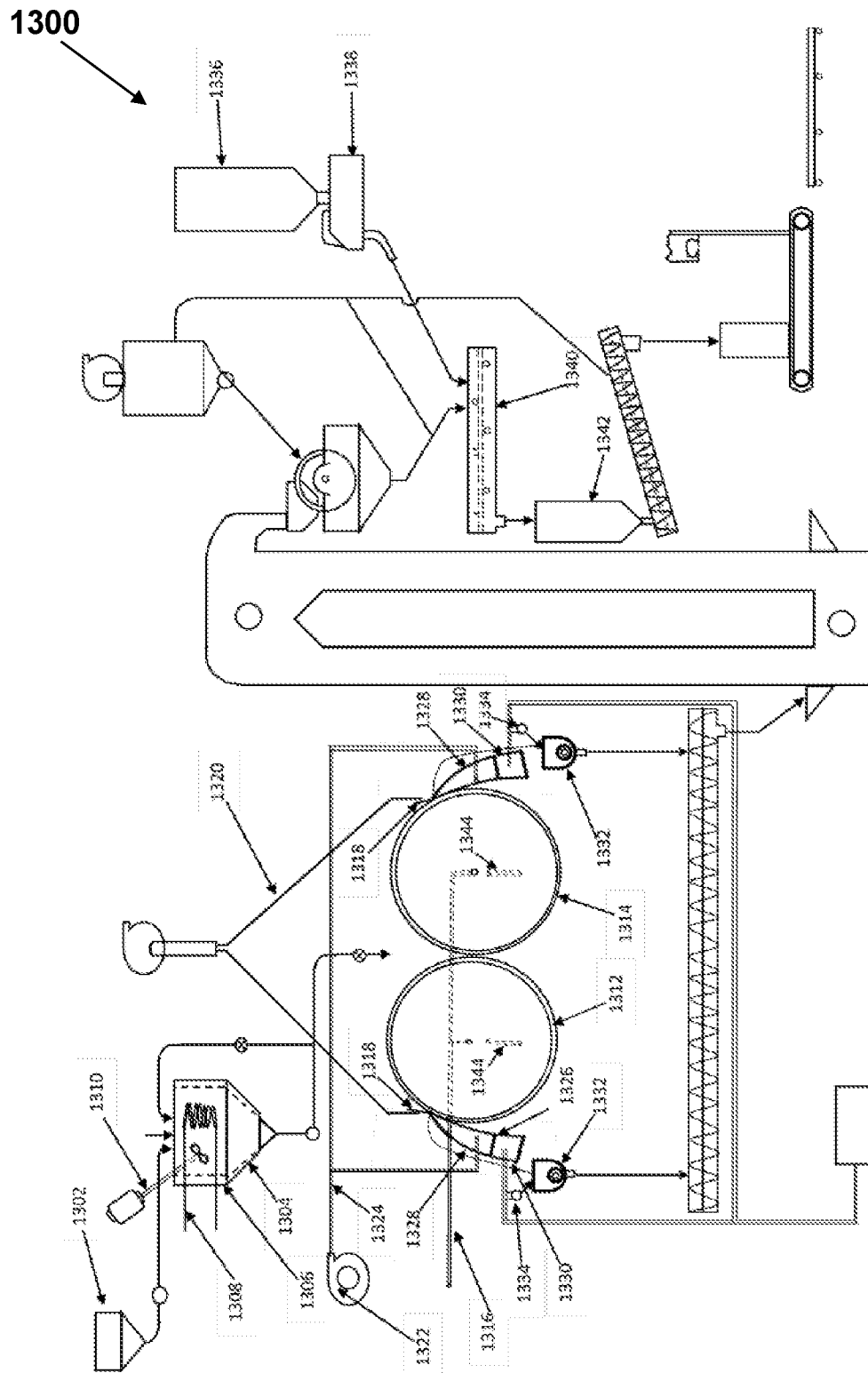


Fig.13

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2019/056245

A. CLASSIFICATION OF SUBJECT MATTER
C10G1/00, C10G3/00 Version=2019.01

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

C10G

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

TotalPatent One, IPO Internal Database

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	Trabelsi, Ada Ben Hassen, Et Al., "Second generation biofuels production from waste cooking oil via pyrolysis process.", Renewable energy Vol 126 (2018), pp 888-896, Available online 03 APRIL 2018 (03-04-2018). See Abstract, pages 10-11, lines 243-250; pages 22-23, lines 432-441; page 16, lines 318-319; Table 3	1-17
A	Mohamed, M. A., Et Al., "Biofuel Production from Used Cooking Oil Using Pyrolysis Process.", International Journal for Research in Applied Science and Engineering Technology Vol 5, Issue XI (2017), pp 2971-2976, Available at www.ijraset.com 30 NOVEMBER 2017 (30-11-2017). See Abstract, page 2973, Fig 2, 3, 5; page 2974	1-17
A	Piloto-Rodriguez, Ramon, Et Al., "Conversion of by-products from the vegetable oil industry into biodiesel and its use in internal combustion engines: a review.", Brazilian Journal of Chemical Engineering Vol. 31, No. 02, pp. 287 - 301, 30 JUNE 2014 (30-06-2014),	1-12



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

14-11-2019

Date of mailing of the international search report

14-11-2019

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/IB2019/056245

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	dx.doi.org/10.1590/0104-6632.20140312s00002763. See Abstract, Fig 1, page 289, Table 1; Table 3 -----	1-12
	US 20160024394 A1, (UNIV ALBERTA[CA]), 28 JANUARY 2016 (28-01-2016) See Para [0005], See claims 1, 2, 5-9, 14, 15, 21-24 -----	
A	US 9255232 B2, (RES USA LLC[US]), 09 FEBRUARY 2016 (09-02-2016) See Abstract	1-12

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2019/056245

Citation	Pub.Date	Family	Pub.Date
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		BR 112015023479 A2	18-07-2017
		CN 105143407 A	09-12-2015
		EP 2970776 A2	20-01-2016
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		CA 2842079 A1	31-01-2013
		EP 2737032 A2	04-06-2014
		ZA 201309750 B	25-09-2014