Bio-diesel synthesis from Kenaf seed oil and performance analysis of its bio-diesel blends on four stroke, Compression Ignition Engine.

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ABSTRACT: *Biodiesel has been a topic of interest since past few years because of its eco-friendly nature, low pollution emitting and non-toxic properties. Globally, there are hundreds of crops which can be used as a biodiesel feedstock. Use of biodiesel reduces dependence on non-renewable sources of energy such as fossil fuels. Oils generally have high viscosity, high density and high flash point and therefore they cannot be directly used as fuel in diesel engine. Suitable process is used in order to synthesize bio-diesel from oil to make its properties similar to that of conventional diesel. In present study, base catalyzed transesterification process has been used in order to get biodiesel from kenaf seed oil. Properties of kenaf seed oil and bio-diesel are comparative to that of conventional diesel. Biodiesel can either be used alone(B100) without any blending or it can be blended with conventional diesel according to ASTM specifications so as to ensure safe operation of CI engine which has been designed for conventional diesel fuel. In present study, objective is to analyze performance of kenaf seed bio-diesel and its blends. n-butanol will be used as an additive. Use of additive will enhance combustion quality of diesel. Engine performance parameters such as brake power (BP), brake specific fuel consumption (BSFC), brake thermal efficiency (BTE), brake specific energy consumption (BSEC) have been measured under various load conditions for different bio-diesel blends and these performance parameters have been compared to that of conventional diesel.*

Key Words: Kenaf seed oil, Bio-diesel, Transesterification, Blending, n-butanol

1. INTRODUCTION

Depleting conventional fuel or fossil fuel resources combined with continuous increase in energy demand has spurred interest for research in area of alternative fuels or biodiesel. Use of biodiesel will result in reduction of pollutants being released due to continuous use of fossil fuels. Biodiesel is generally obtained from renewable energy sources [1]. Petroleum consumption is increasing day by day. A major portion of petroleum is refined to diesel which is mainly used for transportation purpose. Biodiesel production in large scale can help to meet increasing fuel demands. An important factor which favors production of biodiesel is that it will result in reduction in emission of greenhouse gases. Continuous combustion of petroleum products since last few decades has resulted in increase of emissions of carbon dioxide and other greenhouse gases into environment [2]. These greenhouse gases are majorly responsible for global warming, resulting in rise in mean temperature of earth and global warming. If conventional diesel is completely substituted by biodiesel, it will reduce carbon dioxide emissions by 78%.

1.1. Biodiesel

Biodiesel consists of long chain alkyl (methyl, ethyl or propyl) esters of fatty acids. Lipids i.e. oil is made to react with alcohol in presence of a catalyst producing fatty acids ester. Biodiesel can be used effectively in standard diesel engines and that properties are quite different from straight oil. Biodiesel can either be used alone i.e. in form of B100 or it can also be blended with diesel in different proportions. Biodiesel obtained either from vegetable oils or animal fat should meet ASTM D 6751 specifications. Common source of biodiesel includes jatropha, sunflower, mustard, soya bean, palm, jojoba, groundnut, peanut, canola, camelina and cottonseed oil [3]. Biodiesel has good lubricating properties and cetane rating as compared to low sulphur diesel fuel. Fuels having higher lubricity may increase life of fuel injection equipment that depends on fuel for lubrication.

1.2 Kenaf seed oil

Kenaf, Hibiscus Cannabinus, is a plant which belongs to Malvaceae family. It is also known as Deccan hemp or Java jute. This plant is mostly found in southern Asia but its origin is still unknown. Fiber obtained from Kenaf plant has characteristics similar to that of jute. Kenaf is a biennial herbaceous plant near about 1.5 to 3 metre tall. Stems of kenaf have diameter in range of 1 to 2 cm. Its leaves are 10 to 15 cm long having variable shape. Flowers of kenaf have diameter in range of 8 to 15 cm. Their color can either be white, yellow or purple. Fruit is in form of capsule having 2cm diameter. Kenaf seeds are obtained from its fruit. Kenaf is cultivated for its fiber in various countries like India, USA, South Africa, Viet Nam, Thailand, parts of Africa and in some parts of Europe. Kenaf fiber finds application in rope, cloth and paper industry. Kenaf seed oil has a dark brown color and it is quite bitter in taste. It can be used as edible oil and also finds application in cosmetic and lubricant industry. Properties of kenaf seed oil have attracted have attracted attention towards its use for making biodiesel or biofuel. Kenaf seed contains 20% of oil by weight [4]. Oil extracted from kenaf seed has been found to contain significant amount of epoxy acid as glyceride. Various fatty acid contents have been identified in kenaf seed oil such as linoleic acid, oleic acid, palmatic acid, stearic acid and 9-hexadonic acid and traces of arachidic acid.

Fig.1.2.1 Kenaf fruit and its seed

2. LITERATURE REVIEW

Literature review has been done with help of journals related to my topic. They are described as follows:

A.E. Atabani, M.M. Mofijur, H.H. Masjuki, Irfan A. Badruddin, W.T. Chong, S.F. Cheng, S.W. Gouk[1] They studied characteristics of Manketti(Ricinodendron Rautonemii) for biodiesel production. They analyzed fatty acid composition of Manketti methyl ester using gas chromatography. Manketti methyl ester was found to contain 18.3% of fatty acids and 81.7% of unsaturated fatty acids. Biodiesel obtained from Manketti has significant calorific value with better cold flow properties than other methyl esters. Biodiesel was blended with petroleum diesel in order to improve its properties such as Kinematic viscosity and density. B5 blend produced lower brake power, brake fuel specific consumption was higher, Carbon monoxide (CO) and Hydrocarbon (HC) emissions were higher but emission of Nitric oxide (NO) was lower as compared to diesel.

Piyanuch Nakpong, Sasiwimol Wootthikanokkhan [2] they evaluated production of biodiesel from crude Roselle oil. They made use of alkali catalyzed transesterification process in order to obtain biodiesel. Biodiesel was obtained with low free glycerol content. Obtained biodiesel met international standards EN 14214: 2008 and ASTM 6751-07b except for higher carbon residue and lower oxidation stability. They concluded that biodiesel can be successfully produced by alkali catalyzed transesterification process by making use of methanol in presence of potassium hydroxide as a catalyst. Optimum conditions were methanol-to-oil molar ratio of 8:1, catalyst concentration of 1.5% w/w of oil, reaction temperature and time of 60° C and 60 minutes respectively. Biodiesel content was 99.4% w/w at optimum conditions.

S.O. Kareem, E.I. Falokun, S.O. Balogun, O.A. Akinloye, S.O. Omeike [3] they analyzed and compared quality of biodiesel produced from palm oil and palm kernel oil using lipase enzyme as a catalyst. They obtained maximum yield of biodiesel from palm oil and palm kernel oil 95.30% and 86.55% at a temperature of 40°C and molar ratio of 3:1 whereas minimum yield of biodiesel as 89% and 79% respectively at 30°C and molar ratio of 1:1 . They observed that 7.5% of enzyme load and temperature of 40°C were optimum conditions required for biodiesel yield of 95% and 86.04% from palm oil and palm kernel oil, whereas minimum yield of 90% and 82.5% was observed at molar ratio of 1:1 and enzyme load of 2.5% for both palm oil and palm kernel oil respectively. They found out that stoichiometric ratio required for transesterification process was 3-mole of methanol and a mole of oil to yield 3-mole of biodiesel and amole of glycerol. They got to know that biodiesel obtained from palm oil and palm kernel oil have properties that can meet standard requirements but palm oil showed better prospect.

A. Gnanapraksham, V.M. Siva Kumar, A. Surendhar, M. Thirumarimurugan, T. Kannadasan[4] They described biodiesel production from waste cooking oil and various parameters which influences biodiesel production process. They made use of waste cooking oil, generally left after frying, as raw material. They used base catalyzed transesterification process in order to synthesize biodiesel. They found out that fatty acid content in waste cooking oil could be reduced by pre-treating waste cooking oil with acid catalyst. Methanol to oil ratio for acid catalyzed reaction was found to be dependent on amount of free fatty acid. Amount of catalyst was found to be dependent on type of catalyst, whether homogenous or heterogeneous. For base catalyzed reaction, they found optimum molar ratio of methanol and oil to be 6:1.

A. Arun Shankar, Prudhvi Raj Pentapati, R. Krishna Prasad [5] they synthesized biodiesel from cotton seed oil using homogeneous alkali catalyst and heterogeneous multi walled carbon tubes. The transesterification process for conversion of cotton seed oil to biodiesel was performed by varying various factors such as amount of NaOH used, alcohol to molar ratio and reaction time. They analyzed effects of various parameters on yield of biodiesel and biodiesel yield was founded highest at 110°C for alkali concentration of 0.75 g NaOH/l of oil at an alcohol to oil ratio of 7:1. Maximum biodiesel yield was 95%. Properties of biodiesel such as calorific value, flash point, viscosity, density and pour point were found to be satisfactory as per ASTM standards.

3. POLLUTANT EMISSIONS FROM DIESEL ENGINE

Like other fossil fuels, diesel contains chains of carbon and hydrogen. In case of ideal combustion i.e. complete combustion of diesel fuel CO_2 and H_2O will be generated from engine. But due to various factors like air-fuel ratio, air-fuel concentration and combustion temperature, harmful products are generated such as Carbon monoxide (CO), Hydrocarbons (HC), Oxides of Nitrogen (NO_X) AND Particulate Matter (PM). NO_x has highest proportion in exhaust emitted from diesel engines. It is followed by particulate matter which has second highest proportion in exhaust gas. Concentration of CO in exhaust is high when engine makes use of rich air-fuel mixture as all carbon doesn't convert to CO_2. Rich air-fuel mixture is required during starting and acceleration. Hydrocarbons are emitted from diesel engine when fuel doesn't burn completely, generally at light loads [5].

4. BIODIESEL SYNTHESIS PROCESS

Biodiesel can be synthesized from oils using four different process which are pyrolysis, micro-emulsification, dilution and transesterification process. Among all process, base catalyzed transesterification process provides maximum yield of biodiesel and it is cost effective too.

4.1 BASE CATALYSED TRANSESTERIFICATION PROCESS

In this process, reaction of oil and alcohol is carried out in presence of catalyst such as Sodium hydroxide (NaOH) or potassium hydroxide (KOH) in order to produce alkyl esters (biodiesel) and glycerol. High yield of biodiesel can be obtained from this process. Catalysts such as alkaline metal oxide and hydroxide or metal carbonates can also be used. This process is carried out in temperature range of 60-70 degree Celsius. Base catalyzed transesterification process can be used to carry out both small batch as well as high batch production [6].

5. MATERIAL SELECTION AND TRIALS PERFORMED

5.1 SELECTION OF RAW MATERIALS

Kenaf seeds have been selected as a raw material for biodiesel synthesis. Kenaf trees are found in Dhamtari and Gariyabandh districts of Chattisgarh. Seeds were obtained from fruits of kenaf tree and they were dried with help of sunlight for about 15 days. Seeds were dried in order to completely remove moisture content from seeds. Seeds are feed in oil extraction machine and oil is extracted from it. Extracted oil contains small particles in it. Oil is filtered so as to remove particles from it. Filtered oil is used to synthesize biodiesel by making use of base catalyzed transesterification process.

5.2 TRIALS PERFORMED

In first trial, oil sample of 200 ml was taken, 40 ml of ethanol (20% by weight) and 4 gram (2% by weight of sodium hydroxide) were used in order to synthesize biodiesel but biodiesel was not obtained. Glycerol was obtained but biodiesel was not obtained in this trial.

In second trial, methanol and potassium hydroxide were used in order to synthesize biodiesel and biodiesel and glycerol was obtained. Following are the steps performed in order to make biodiesel:

1. Take oil sample of 200 ml in a flask.

2. Heat oil at 60°C for 30 minutes and stir it regularly with time interval of 5 minutes.

Fig 5.2.1: Oil sample being heated

3. Mix methanol and potassium hydroxide (KOH) with each other by shaking them together manually in a bottle.

4. Once oil gets heated, add mixture of methanol and KOH to oil and stir them with magnetic stirrer for 15 minutes.

5. Pour mixture in separating funnel and left it undisturbed for 3 hours. Since biodiesel is lighter than glycerol, glycerol will settle down at bottom and biodiesel will float at top.

Fig5.2.2 Biodiesel and glycerol separation

6. Boil tap water at 100°C for 30 minutes.

7. Mix biodiesel and boiled water in equal proportions.

8. Left mixture undisturbed for 3 hours. Since water is heavier than biodiesel, water will settle down at bottom and washed biodiesel will float at top.

8. Biodiesel obtained from first wash has soap contents present in it.

9. Wash biodiesel again with hot water.

10. Triple wash biodiesel with hot water in order to completely remove soap content from biodiesel.

Fig. 5.2.3: Separation of biodiesel and water after final wash

11. Heat biodiesel at 100°C for 30 minutes in order to completely remove traces of water present in it.

Fig. 5.2.4: Heating of biodiesel

Thus, biodiesel obtained at end doesn't contain any impurities in it can be further used according to requirement. It can either be used alone or blended to modify some of its properties.

Following table shows different amounts of biodiesel obtained when methanol was used in varying amount keeping quantity of oil(200 ml) and amount of catalyst i.e. potassium hydroxide(4 gram) constant.

Serial No.	Oil sample	Amount of methanol	Amount of catalyst	Biodiesel obtained
1	200 ml	20 ml	4 gram	120 ml
2	200 ml	30 ml	4 gram	150 ml
3	200 ml	40 ml	4 gram	185 ml
4	200 ml	50 ml	4 gram	175 ml
5	200 ml	60 ml	4 gram	180 ml
6	200 ml	70 ml	4 gram	195 ml
7	200 ml	80 ml	4 gram	197 ml

Table 5.2.1: Biodiesel obtained from conversion process

From above table, it can be inferred that yield of obtained biodiesel was minimum when 20 ml of methanol was used i.e. 10% by volume and yield of biodiesel was maximum when 80 ml of methanol was used i.e. 40% by volume.

In third trial, amount of potassium hydroxide was changed keeping quantity of methanol and quantity of oil sample unchanged. When 6 grams and 8 grams of potassium hydroxide were used as catalyst instead of 4 grams, separation of biodiesel and glycerol didn't take place.

6. BIODIESEL AND PETROLEUM DIESEL PROPERTIES

Properties of kenaf seed biodiesel have been described below:

Property	Unit	Method	Value
Acid value	mg KOH/g	ASTM D664	1.13
Calorific Value	KJ/Kg	ASTM D240	37434.9
Density(at 15°C)	Kg/m^3	ASTM D1298	0.879
Flash point	°C	ASTM D93	130
Viscosity(at 40°C)	mm^2/s	ASTM D445	3.77

Table 6.1: Kenaf seed biodiesel properties

Values of all major properties have been found satisfactory but acid number is quite high because obtained biodiesel is not refined.

Following are properties of petroleum diesel:

Property	Unit	Value
Calorific Value	KJ/Kg	45280
Cetane number	_	54.6
Density(at 15°C)	Kg/m^3	853

Flash point	°C	65
Viscosity(at 40°C)	mm^2/s	2.8

Table 6.2: Properties of petroleum diesel

7. BIODISEL ADDITIVES

Additives are blended with biodiesel in order to modify or enhance its properties [7] Some of additives are described as follows:

Ethanol:

Ethanol can be obtained by process of fermentation of different feed stocks such as sugarcane, sunflower, corn, wheat, cotton etc. Ethanol contains 34% more oxygen in it. Blending small amount of ethanol can increase brake thermal efficiency, rate of heat release and reduces viscosity and smoke content in exhaust. It also improves combustion.

Methanol:

Methanol has high level of oxygen present in it. Latent heat of methanol is also high (1109 KJ/Kg) as compared to diesel which makes it suitable for being used as an additive.

Diethyl ether:

Diethyl ether has high volatility and flammability. Its cetane index is also high. But its hating value is lower than petroleum diesel. Use of diethyl ether as an additive improves performance of engine and reduces pollutant emission.

n- Butanol:

n- Butanol also has good oxygen content in it. It is obtained from process of fermentation. n-butanol has straight chain with hydroxyl group attached to it. High cetane number, high solubility and heat content are some of significant properties of n-Butanol.

Following are some of properties of additives:

Additive	Calorific Value (KJ/kg)	Density (kg/m^3)	Kinematic viscosity at 40°C (mm^2/sec)	Flash point(°C)
Ethanol	27333	791	1.14	12.77
Methanol	19620	790	0.59	11.11
Diethyl ether	33890	712	0.22	-45°C
n- Butanol	34330	812	3.0	35

Table 6.3: Properties of some additives

8. BLEND PREPARATION AND PERFORMANCE ANALYSIS

8.1 BLEND PREPARATION Following are eight different blends which have been made and will be tested:

Blend A: (5% kenaf biodiesel+90% diesel+5% n-butanol)

Blend B: (10% kenaf biodiesel+85% diesel+5% n-butanol)

Blend C: (15% kenaf biodiesel+80% diesel+5% n-butanol)

Blend D: (20% kenaf biodiesel+75% diesel+5% n-butanol)

Blend E: (25% kenaf biodiesel+70% diesel+5% n-butanol)

Blend F: (30% kenaf biodiesel+65% diesel+ 5% n-butanol)

Blend G: (35% kenaf biodiesel+ 60% diesel+ 5% n-butanol)

Blend H: (40% kenaf biodiesel+ 55% diesel+5% n-butanol)

Amount of biodiesel, diesel and n-butanol in different 200 ml test sample blends are as follows:

Blend Name	Amount of biodiesel in 200 ml blend	Amount of diesel in 200ml blend	Amount of n-butanol in 200 ml blend
Blend A	10 ml	180 ml	10 ml
Blend B	20 ml	170 ml	10 ml
Blend C	30 ml	160 ml	10 ml
Blend D	40 ml	150 ml	10 ml
Blend E	50 ml	140 ml	10 ml
Blend F	60 ml	130 ml	10 ml
Blend G	70 ml	120 ml	10 ml
Blend H	80 ml	110 ml	10 ml

Table 8.1.1: Sample Blends

8.2 TEST SET UP

Fig 8.2.1 Test Setup

It consists of diesel engine i.e. four stroke Compression Ignition engine which is connected to hydraulic dynamometer. Load test can be performed on setup. It is water cooled type. Other arrangement includes fuel measuring system, air measuring system and thermocouple is used in order to maintain temperature. Various parts of setup are as follows:

8.2.1 ENGINE

It is four stroke, single cylinder engine manufactured by kirloskar. It has compression ratio of 16.5:1. Load is added to engine with help of hydraulic dynamometer. Bore of engine is 80 mm whereas stroke of engine is 110 mm. It has brake horse power of 5 H.P.

8.2.2 DYNAMOMETER

In order to analyze performance parameters under various load conditions, hydraulic dynamometer is used. Valves of dynamometer are closed to increase load on engine. Spring balance has been used to measure load. An important parameter used to calculate torque is distance between center of spring balance and center of dynamometer shaft. Its value is 0.34 m in this set up.

8.3 PERFORMANCE PARAMETERS

In order to analyze performance of engine upon use of biodiesel blends, performance parameters are required. Following are performance parameters which will be used in this work:

Brake power:

Power developed by engine at output shaft is known as brake power. It doesn't include power loss caused by gear, friction and other factors.

Brake Specific fuel consumption:

It is ratio of rate of fuel consumption to power output. It denotes fuel efficiency of engine which makes use of fuel and delivers power, which may be shaft power or rotational power.

Brake Specific energy consumption:

It is ratio of energy obtained from fuel per unit time to brake power obtained from shaft. It indicates how effectively energy is obtained from fuel used.

Brake thermal efficiency:

It is defined as ratio of brake power obtained to heat supplied to engine. It evaluates efficiency of an engine to convert thermal energy of fuel to mechanical energy.

8.4 Formulas used

Following are formulas used for calculating performance parameters:

1. Amount of fuel consumed:

$$m_f = \frac{X}{t} \text{ X } \frac{Specific\ Gravity}{1000}$$

where, m_f is amount of fuel consumed in kg/sec

X is volume of fuel consumed in ml

t is time required to consume X(ml) of fuel in seconds

2. Heat supplied to engine:

$$Q_f = m_f \text{ x C.V.}$$

Where, Q_f is heat supplied to engine

C.V. is calorific value in KJ/Kg

3. Brake Power,

$$\text{B.P.} = \frac{2\pi NT}{60000}$$

Where, B.P. IS Brake Power in kilowatts

T is torque in N.m.

T = P x r x 9.81

P is net load in kg

r is distance between canter of spring balance and center of spring shaft

4. Brake Specific Fuel Consumption:

$$\text{B.S.F.C.} = \frac{mf \text{ X } 3600}{Brake\ power}$$

Where B.S.F.C is Brake Specific Fuel Consumption in Kg/KW-hr

5. Brake Specific Energy Consumption:

$$\text{B.S.E.C} = \frac{B.S.F.C \text{ X } Calorific\ Value}{1000}$$

B.S.E.C is Brake Specific Energy Consumption in MJ/Kw-hr

6. Brake thermal Efficiency:

$$h = \frac{Brake\ Power}{Heat\ Supplied}$$

Where, h is Brake thermal efficiency and is unit less

8.4 Performance Analysis:

In order to analyze performance, different performance parameters are needed to be calculated under varying load conditions. It is needed to record data such as time required to consume 20 ml of fuel, speed of shaft. Test is first performed with pure diesel and values are recorded. Test is then performed with other blends i.e. Blend A, Blend B, Blend C, Blend D, Blend E, Blend F, Blend G and Blend H.

All data obtained after performing tests and calculated values have been recorded in tabular form as follows:

Pure diesel i.e. 100% diesel

S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	109	1584
2	1	102.4	1563
3	2	91.2	1530
4	3	82	1519
5	4	74.8	1508
6	5	69	1500

Table 8.4.1: Data for 100% diesel

S No.	Brake Power(KW)	Brake Specific Fuel Consumption(Kg/Kw-hr)	Brake Specific Energy Consumption(MJ/Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.54	1.11	50.1	7.2
3	1.07	0.63	28.59	12.6
4	1.59	0.47	21.32	16.9
5	2.11	0.39	17.61	20.4
6	2.62	0.34	15.37	23.4

Table 8.4.2: Calculated performance parameters for 100% diesel

Blend A (5% biodiesel+ 90% diesel+ 5% n-butanol)

S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	111.2	1658
2	1	102	1612
3	2	96	1550
4	3	89	1510
5	4	78.8	1472
6	5	70.4	1446

Table 8.4.3: Data for Blend A

S No.	Brake Power (KW)	Brake Specific Fuel Consumption (Kg/Kw-hr)	Brake Specific Energy Consumption(MJ /Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.56	1.07	47.6	7.6
3	1.08	0.59	26.3	13.7
4	1.58	0.44	19.4	18.6
5	2.06	0.38	16.74	21.5
6	2.52	0.34	15.08	23.5

Table 8.4.4: Calculated performance parameters for Blend A

Blend B: (10% biodiesel+ 85% diesel+ 5% n-butanol)

S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	114.2	1620
2	1	102	1578
3	2	88	1530
4	3	76.2	1512
5	4	68.8	1493
6	5	60.4	1468

Table 8.4.5: Data for Blend B

S No.	Brake Power (KW)	Brake Specific Fuel Consumption (Kg/Kw-hr)	Brake Specific Energy Consumption(MJ /Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.55	1.1	48.34	7.4
3	1.07	0.65	28.7	12.6
4	1.58	0.51	22.41	16
5	2.08	0.43	18.9	19.1
6	2.56	0.4	17.6	20.6

Table 8.4.6: Calculated performance parameters for Blend B

Blend C: (15% biodiesel+ 80% diesel+ 5% n-butanol)

S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	140	1616
2	1	124	1572
3	2	105.6	1554
4	3	90	1538

5	4	80.4	1512
6	5	70.4	1506

Table 8.5.7: Data for Blend C

S No.	Brake Power (KW)	Brake Specific Fuel Consumption(Kg/Kw-hr)	Brake Specific Energy Consumption(MJ/Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.55	0.9	39.33	9.1
3	1.08	0.54	23.52	15.3
4	1.61	0.42	18.29	19.4
5	2.11	0.36	15.68	22.7
6	2.63	0.33	14.49	24.4

Table 8.4.8: Calculated performance parameters for Blend C

Blend D: (20% biodiesel+ 75% diesel+ 5% n-butanol)

S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	134.8	1650
2	1	116	1610
3	2	101.2	1583
4	3	88	1552
5	4	84	1518
6	5	74	1504

Table 8.4.9: Data for Blend D

S No.	Brake Power (KW)	Brake Specific Fuel Consumption (Kg/Kw-hr)	Brake Specific Energy Consumption(MJ/Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.56	0.95	40.92	8.7
3	1.1	0.55	23.87	15.1
4	1.62	0.42	18.13	19.3
5	2.12	0.35	14,95	24.1
6	2.62	0.32	13.7	26.3

Table 8.4.10: Calculated performance parameters for Blend D

Blend E: (25% biodiesel+ 70% diesel+ 5% n-butanol)

S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	121.6	1700
2	1	110.4	1650
3	2	103.6	1590
4	3	89.8	1550
5	4	78.8	1414
6	5	67.2	1482

Table 8.4.11: Data for Blend E

S No.	Brake Power (KW)	Brake Specific Fuel Consumption (Kg/Kw-hr)	Brake Specific Energy Consumption(MJ/Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.58	0.97	41.43	8.7
3	1.11	0.54	22.89	15.7
4	1.62	0.43	18.53	19.4
5	2.12	0.37	15.83	22.7
6	2.59	0.35	15.16	23.7

Table 8.4.12: Calculated performance parameters for Blend E

Blend F: (30% biodiesel+ 65% diesel+ 5% n-butanol)

S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	123.6	1688
2	1	108	1640
3	2	94	1624
4	3	83.6	1564
5	4	74.4	1524
6	5	68.6	1500

Table 8.4.13: Data for Blend F

S No.	Brake Power (KW)	Brake Specific Fuel Consumption (Kg/Kw-hr)	Brake Specific Energy Consumption(MJ/Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.57	1	42.55	8.4
3	1.14	0.58	24.5	14.7
4	1.64	0.45	19.1	18.9

5	2.13	0.39	16.54	21.8
6	2.62	0.34	14.56	24.7

Table 8.4.14: Calculated performance parameters for Blend F

Blend G: (35% biodiesel+ 60% diesel+ 5% n-butanol)

S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	117.2	1590
2	1	104.6	1558
3	2	95.2	1536
4	3	86.6	1529
5	4	79.6	1508
6	5	72	1498

Table 8.4.15: Data for Blend G

S No.	Brake Power (KW)	Brake Specific Fuel Consumption (Kg/Kw-hr)	Brake Specific Energy Consumption(MJ /Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.54	1.09	45.9	7.8
3	1.07	0.6	25.4	14.2
4	1.6	0.45	18.8	19.1
5	2.11	0.37	15.57	23.3
6	2.62	0.33	13.79	26.1

Table 8.4.16: Calculated performance parameters for Blend G

Blend H: (40% biodiesel+ 55% diesel+ 5% n-butanol)

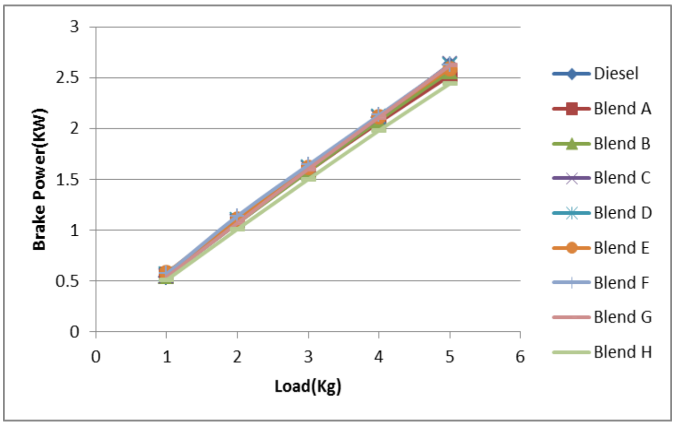
S No.	Load on engine(Kg)	Time taken to consume 20 ml of fuel sample	Speed of shaft (RPM)
1	0	126.4	1478
2	1	114	1463
3	2	104	1448
4	3	90	1428
5	4	72.4	1419
6	5	60	1396

Table 8.4.17: Data for Blend H

S No.	Brake Power (KW)	Brake Specific Fuel Consumption (Kg/Kw-hr)	Brake Specific Energy Consumption(MJ /Kw-hr)	Brake Thermal efficiency (%)
1	_	_	_	_
2	0.51	1.06	44.36	8.1
3	1.01	0.59	24.61	14.6
4	1.5	0.46	19.07	18.9
5	1.98	0.43	17.77	20.2
6	2.44	0.42	17.61	20.4

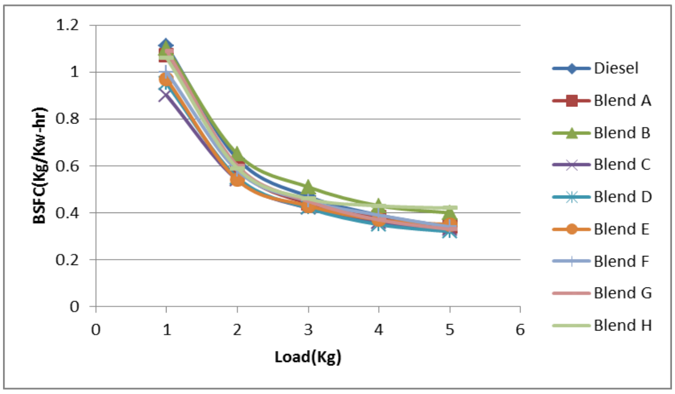
Table 8.4.18: Calculated performance parameters for Blend H

9. RESULTS AND DISCUSSIONS



Graph 9.1: BP versus Load

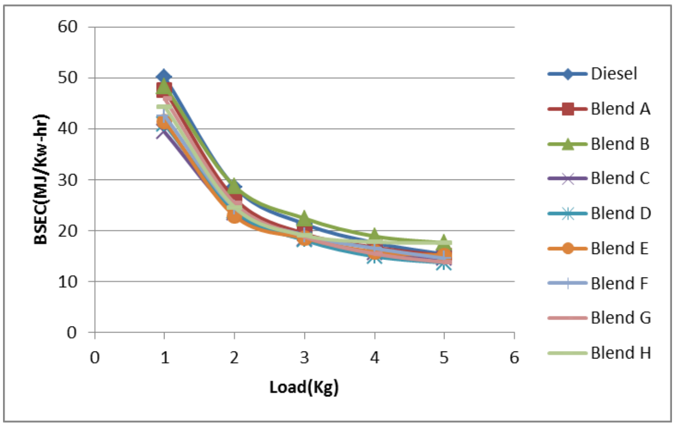
Graph 9.1 shows variation of brake power with load for diesel and all biodiesel blends. Biodiesel blends have shown performance characteristics similar to that of diesel. Brake Power of Blend D is higher than diesel for load conditions of 1, 2, 3 and 4 Kg whereas brake power of Blend H is lower than diesel for all load conditions.



Graph 9.2: BSFC versus Load

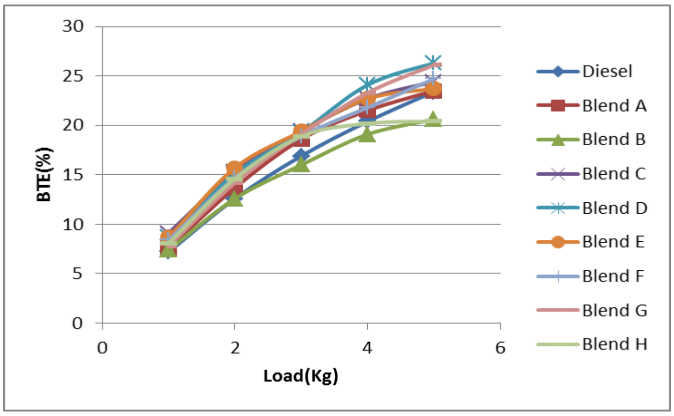
Graph 9.2 shows variation of Brake Specific Fuel Consumption with load for all diesel and biodiesel blends.

Brake Specific Fuel Consumption for all biodiesel blends is lower than that of diesel for load condition of 1 kg whereas it is higher than diesel for Blend B, E and H at load condition of 5 Kg.



Graph 9.3: BSEC versus Load

Graph 9.3 shows variation of Brake Specific Energy Consumption with load for diesel and all biodiesel blends. BSEC for all blends is lower than diesel at load condition of 1 Kg whereas Brake Specific Energy Consumption for Blend B is higher than diesel for load conditions of 2, 3, 4 and 5 Kg.



Graph 9.4: BTE versus Load

Graph 9.4 shows variation of Brake Thermal Efficiency with load for diesel and all biodiesel blends. Brake Thermal Efficiency for all blends is higher than diesel at load condition of 1 kg whereas Break Thermal Efficiency for Blend B and Blend H is lower than that of diesel at load condition of 4 Kg and 5 kg.

10. CONCLUSIONS

Kenaf seed based biodiesel has all desirable properties of fuel which makes it a good option for alternative source of fuel.98.5% of biodiesel yield has been obtained from kenaf seed oil when 40% of methanol (by volume) is used for base catalyzed transesterification process. Biodiesel blends of Kenaf seed biodiesel with diesel and n-butanol have shown good performance characteristics at all load conditions; especially at middle load conditions of 2, 3 and 4 kg.

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