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Experimental Investigation of Performance and Emission Characteristics of Cebia petandra Biodiesel in CI Engine

A.R.Palanivelrajan* and G.Anbarasu

Department of Thermal Engineering, Sri Ramakrishna Engineering College, Coimbatore, Tamilnadu, India

Abstract: Industrialization throughout the globe has increased in past two decades which in turn being the reason for decrease in the Fossil Fuels. The decrease in Fossil Fuels has resulted in research of alternate fuels which can efficiently decrease the usage of fossil fuel consumption either by direct usage of Alternate fuel or in addition with fossil fuel produced Petroleum Product such as Petrol/Diesel. The Experimental Project work was inspired from the increasing research work that has been done in the field of "BIOFUELS" produced from the non-edible oils. The non-edible oil used in the project is extracted from Cebia Pentandra seed (silk cotton seed, Kapok seed), through two step esterification process the oil is converted to Biodiesel. Five different Blends of Biodiesel-Diesel is used, whose Engine performance and emission characteristics are studied by fueling CI engine at constant compression ratio. In this experimental work the results of Engine Performance and Emission characteristics of the Biodiesel Blends are compared to the Diesel Performance and emission characteristics.
Keywords : Alternate Fuels, Biofuels, Non-edible oils, Silk cotton seed oil, Methyl Ester, Biodiesel Blends, Performance and Emission characteristics, Two step esterification, CI Engine.

1. Introduction:

"Globalization is one important reason for growth of most developing countries. Through Globalization, native resource of each country is identified and utilized to produce products which are globally marketed and thereby increasing the country's industrialization. Industrialization growth of developing countries is positive on the country's economy development besides there are also negative effect on the country such as increasing energy consumption of the developing countries which leads the global climatic change. In last one decade the world's 75% of fossil fuel resources has been used for the increasing energy demand. Further usage of fossil fuel leads to fuel crisis which in turn cause the energy crisis. To meet the energy crisis throughout the world, countries have been focusing to harness the "Non-Conventional Energy Source" to balance the energy demand. "India" is one among the most important developing countries. India being a huge global market for number of multinational companies and their product's, also with India's rich natural resources multinational companies build their industries and utilize the native resource. India has geographical benefit with various alternative sources such as Solar, Wind, Hydro, Tidal, Geothermal and Biofuels[6]. India with all its versatile alternative resources still is dependent on thermal power station which are run on the conventional fossil fuel to meet its energy demand. Among the worlds the world's major Green House Gas developer's India is ranked number 4th and ranked as number 4th in Energy consumption. In India the import of oil has increase by 30% from 1990 to 2012, further the current status of oil import must be higher than that of 30%. The rise in the oil import is due to the Transport sector which consumes the major of imported oil for the fuel requirement[1]. The increasing price of oil barrels and air pollution caused by the petroleum product is emerging as a threat to India, so to produce energy from Non-conventional source India focused on wind, solar, hydro etc., but in case of transport sector it requires liquid fuel to reduce its crude oil consumption, Indian government focused on Biofuels, fuel produced from oil from the waste organic vegetable oil, organic matter can be added to the conventional petroleum fuels to reduce the oil consumption by the transport sector. The biofuel production initially was dependent on ethanol produced from sugarcane and biodiesel produced from edible oil. Indian Biofuel Policies was framed with conceptualization of blending 5% of ethanol (or) Biodiesel with the conventional petroleum fuel[2]. Further the Indian biofuel policy was revived to rise the blending to 10% from 5% thereby further more reduction of crude oil consumption. Due to fluctuating sugarcane production and low edible oil content feed stocks, the mandatory policy couldn't be efficiently implemented. Further adding obstacles to the Biofuel policy, "Life Cycle Analysis" a research study done on the potential of Biofuel and effects caused by biofuel either directly (or) indirectly[3]. LCA also confirmed that if the Biofuel production continued this would cause a significant food versus fuel crisis. The lead the Indian government to initiate research over non-edible oil in production of biodiesel which could mandate the "Biodiesel Blending" with fuel by the oil marketing companies. Thus research of non-edible increase in India with this "Second Generation Biodiesel" came into existence in India. Further the government revived the biofuel policy and recommended launching of national mission on Biodiesel based on non-edible tress-borne-oils.

Second Generation Biodiesel are those produced from non-edible oil extracted from feed stocks such as Jatropha curcas, calophyllum inophyllum, sterculia foetida, pongamia pinnata, cotton seed, silk cotton seed and rubber seeds etc[4]. Indian government chose Jatropha Curcas as one potential oil yielding crop and government provided fiscal incentives through central and state governments to achieve mandatory biofuel blending programme. Though the non-edible oil produced biodiesel from jatropha curcas met the ASTM properties of Biodiesel, still the Indian government had to face major stumbling block on its road to Biofuel Blending Programme. The amount of oil obtained from the jatropha curcas feed stock was not sufficient to the demand of biofuel requirement for blending, due to land ownership issues and lackluster progress from the state governments and poor crop quality. The gestation period of the crops also played an important role in oil yield and longer payback time for the land owner or investor and more over produced biodiesel is used by companies for self-use or certain transport companies to reduce their money transaction in terms of fuel[3]. The government has also introduced special incentives and subsides to small or marginal land owners, laborers etc to make their waste land to cultivate the Non-edible oil producing feed stocks. On the interest shown by the government in the field of biofuel's, researches have tired in many different non-edible oil to produce biodiesel and also have studied how far the potential of Biodiesel is in terms of oil yielding. There are so many emerging non-edible oil feed stocks in second generation biodiesel and still researches are perused to meet the government demand of blending 20% of biodiesel or bio-ethanol with petroleum fuel by 2017[5].

India through it revived biofuel Policies and incentives can pioneer in the field of biofuel with variety of feed stocks producing non-edible oil. In this experimental work cebia petandra seed oil is used to produce biodiesel and it is performance and emission characteristics are studied on CI Engine. Cebia Petandra seeds are potential feed stocks which is yet to be explored and in past few it has been under research to manage the oil requirement and to account in the list of feed stocks as a viable oil producer in drought conditions too.

2. Cebia petandra Seed Oil; Characteristics, Esterification process and Biodiesel Properties:

Cebia pentandra is the botanical name of the tree and it belongs to "malvales" family of Plantae kingdom. The tree also has number of Common names such as ceiba, white silk-cotton, java cotton, samauma, kekabu and Illavam Panchu[7] etc. the tree is native of India, srilanka, west Africa and tropical America. Kapok is the most utilized normal name for the tree and might likewise allude to the cotton-such as cushion acquired from its seed units. The tree is drought resistant. The fibre is of most useful which is used for commercial proposes and amount of oil content can be extracted from the seed is about 25-30%[7]. The extracted oil is pleasant in odour. Properties of Kapok Seed oil in given in Table 1.

Table 1. Properties of Kapok Seed Oil

Property	kapok
Kinematic Viscocity at 40^{o}c in cSt	30.2
Flash Point (^{o}c)	262
calorific value(MJ/Kg)	39.59
Acid Value	21
Cetane Number	37

2.1. Esterification of Cebia petandra seed oil:

For conversion of the raw oil to biodiesel, "Two step esterification" process was done with first step as acid pretreatment and second step alkali esterification[8]. To reduce the acidic value, acid catalyst pretreatment process was carried in presence of sulfuric acid for 3hours at 60^{o}C. The methanol to oil ration used in the pretreatment process is 6:1 by volume/volume method. The acid pretreatment process was carried until the acid value of raw reduce to a permissible limit entire mixture of the oil, methanol and sulfuric acid was stirred at constant rpm using a magnetic stirrer[9]. Post the acid pretreatment the excess sulfuric acid was removed and the in same mixture alkali catalyst Potassium Hydroxide is added for the second step of the esterification process to happen through which biodiesel is yielded, the is KoH added in the alkali catalyst reaction also on Volume/Volume. The conversion reaction was again carried for 3 hours and the end products obtained once the reaction completes are Kapok Methyl Ester (Biodiesel) and Glycerol. The result are formed in two distinct layers, upper layer was identified to be Biodiesel and the bottom layer is Glycerol, further separation process was done using separating funnel[10,11].

2.2. Blends and Properties of Kapok methyl ester:

The Biodiesel obtained through esterification process is to be blended with diesel to form various blends of diesel-biodiesel. The property values of the obtained biodiesel were in the permissible of the ASTM and BIS standards, which strongly proved that the Kapok Seed oil is potential source for biodiesel production and the biodiesel produced is also commercial viable which can be used as alternative fuel[12]. The Diesel-Biodiesel blends used in this experimental project work are B10, B20, B30, B40 and B50. In the below table 2 properties of B100 Kapok Methyl Ester is given.

Table 2. Properties of Kapok Oil Methyl Ester (KOME)

Properties	B100 (KOME)
Density at 15^{o}C (gm/cc)	0.8834
Kinematic Viscosity at 40^{o}C (cst)	4.67
Flash Point(^{o}C)	38
Fire Point (^{o}C)	48
Gross Calorific Value (KJ/Kg)	36856.9
cetane Index	48

3. Research Engine Setup:

The various blends of biodiesel produced are tested in Research CI engine. The CI engine setup consists of single cylinder direct injection diesel engine which is fitted with electro-dynamometer, AVL DiGas 444 gas analyzer with sensor modules[13, 14]. The research engine specifications are given in table 3. The blends of biodiesel was tested at engine rpm of 1500, with five different conditions (i.e) no load condition, 25%, 50%, 75% & 100% load conditions.

The research engine measurement module is automated computer enabled with "Enginesoft" engine performance analysis software. The occurrence of uncertainties is highly rare and further occurrence of uncertainties are checked with respect to measured values and it is corrected. The range of uncertainty if any in the work is 1% and below, even in uncertainties in emission are checked.

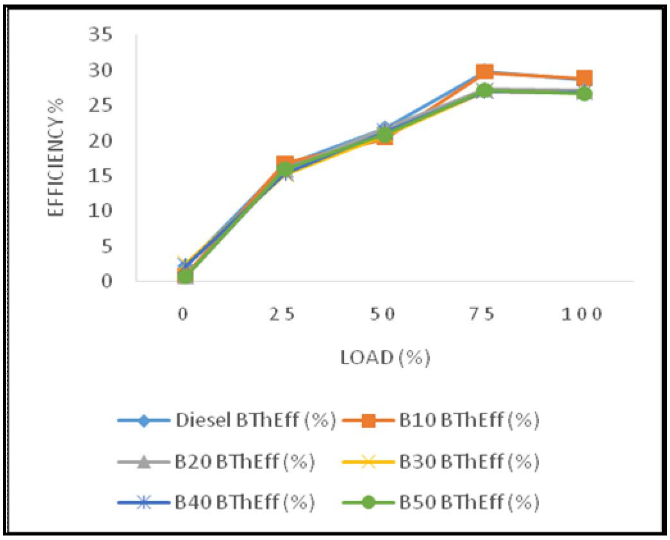
Table 3. Technical specification of the engine

Make	Kirloskar
No of cylinders	single cylinder
Cylinder diameter	87.5 mm
Stroke Length	110 mm
Injection type	direct injection
Type	Compression ignition
compression ratio	17.5:1
rated power	3.5 Kw 1500 rpm
load device	Eddy current dynamometer
cooling type	water cooled

4. Results and Discussion:

4.1. Brake Thermal Efficiency:

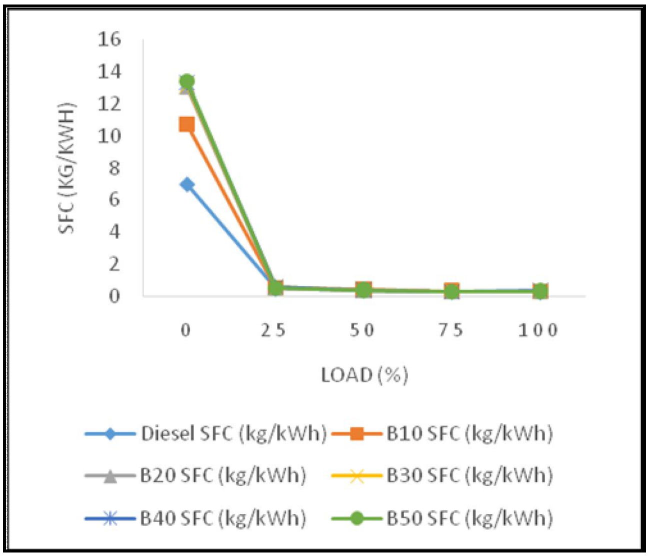
The inference observed from the graph 1 is that the BTE increased with increasing load and at particular load that is at 75% of load there was drop in the BTE for almost all the different blends used, it was the same for diesel also. The maximum BTE for diesel was 29.85% at 75% of load, similarly BTE for B10 29.72%, B20 27.34, B30 27.05, B40 27.07 and B50 27.17. From the above BTE's of Biodiesel B10 showed high BTE among the Biodiesel blends and the BTE of B10 was a close to that of Diesel, which is due to calorific value, cetane number and kinematic viscosity all those in comparable range with that of diesel. The cetane number being close that of the diesel the ignition delay was shorter.



Graph 1. Load Vs Brake Thermal Efficiency

4.2. Specific fuel consumption:

Graph 2,specific consumption Vs load. Generally the specific fuel consumption decreases with increase in the engine load[15]. When the concentration of the Kopak methyl ester increases in blends the specific fuel consumption increase with increase in load when compared with that of diesel (i.e.) for rich blends of Kopak Biodiesel SFC increases with increasing engine load. In the graph there is large deviation in the sfc out of which the B10 sfc is much better when compared to that of other biodiesel blends.



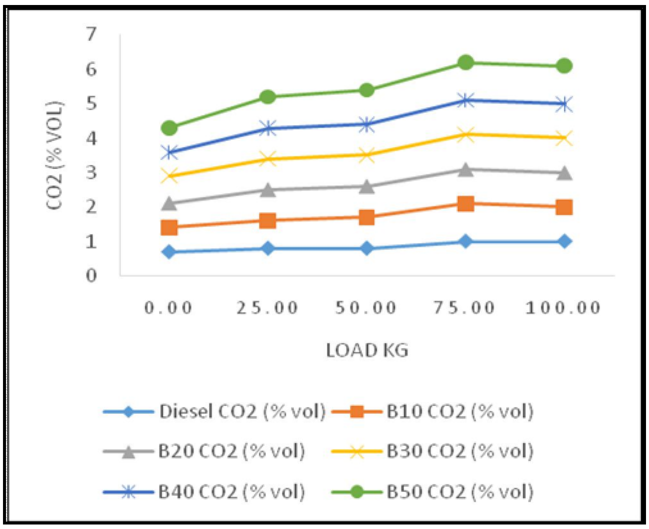
Graph 2. Load Vs Specific Fuel Consumption

4.3. Emission characteristics:

The engine performance characteristics is very important to determine the efficiency of the engine, when different fuels are used in an engine. On other hand not only the engine performance and efficiency is alone important in this pollution increasing world, so the purpose of emission analysis is to know the kind of emission is given by alternate fuel used as a substitute for conventional diesel. The emission is analyzed through exhaust gas from the engine and exhaust gas is comprised of 5 gases[16] Viz,.carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NO_x), oxygen(O_2), Exhaust Gas Temperature and Hydrocarbons (HC). From the above 5 gases majorly considered are CO, NO_x, CO_2 and HC, the amount of these components in the exhaust gas is measured. The variations in exhaust gas with increase in kopak methyl ester concentration and also increase in exhaust gas temperature with increase in engine load is also represented in graphs.

4.3.1. CO2 emission:

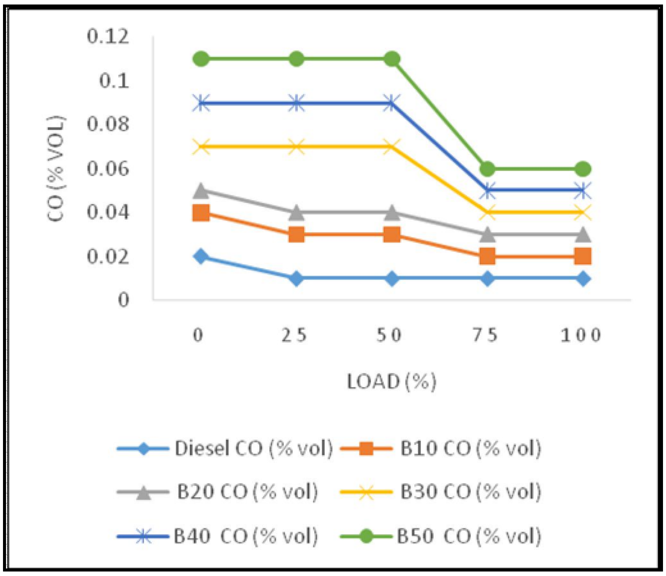
Carbon dioxide most important emission of any internal combustion, it is also a main contender of the Global warming[16]. The CO_2 emission for diesel and various blends of Kopak methyl ester with diesel is measure and represented in Graph 3. The graph shows that with increase in the concentration of KOME, CO_2 increases for richer mixture of blend. Graph 3. CO_2 Emission w.r.t load.



Graph 3. Load Vs CO_2 emission

4.3.2. CO emission:

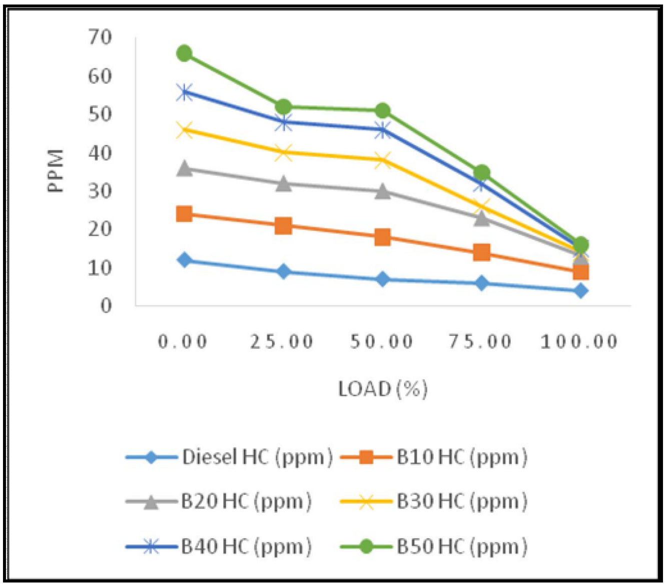
From the above CO_2 emission measurement itself it was observed that complete combustion of fuels occurs with addition of Kapok Methyl ester with diesel in whatever concentration it is added, adding strength to the point. Initially for loads such as 25%, 50% there were slight fluctuation of the CO values but when the engine reached at steady state with 75%, 100% loading the CO emission was much reduced and it was moreover same for all blends with respect to diesel also, this shows that complete combustion of the fuel occurs. Further addition of concentration of the KOME will lead to only complete combustion than that of diesel, emission of CO is given in graph 4.



Graph 4. Load Vs CO emission

4.3.3. HC emission:

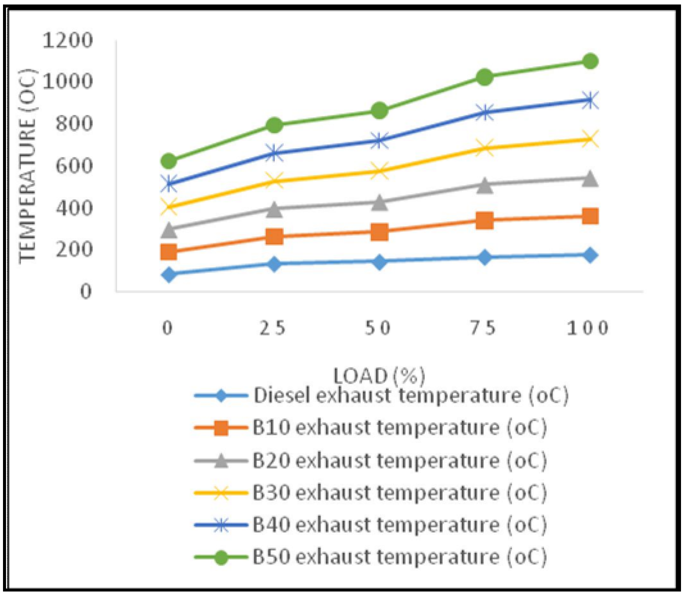
The comparison of HC of KOME and diesel are given in Graph 5. The HC emission decreases with increase in concentration of biodiesel. for leaner blend B10,B20 and for diesel the HC emission was high when compared to the HC emission of B30, B40, B50 etc. at 100 % load the variation are distinctly seen, with further increase in concentration of biodiesel can lead to slight increase in HC when 100% load is attained.



Graph 5. Load Vs HC emission

4.3.4. Exhaust Gas Temperature:

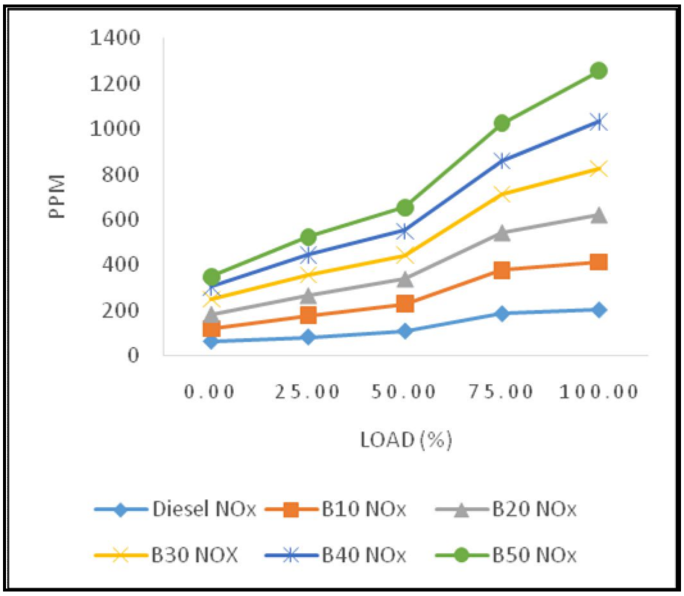
Generally relation observed in engine load and exhaust temperature is that the gas temperature increases with increase in engine load which was in common with all the fuels used in the engine test. The exhaust gas temperature of the B10 blend showed near close temperature of diesel exhaust gas. The higher the exhaust gas which means the more loss of heat energy with exhaust gas. In comparison between the biodiesel blends itself B20, B30, B40 and B50 showed high exhaust gas temperature at full loads condition. The lower exhaust gas temperature of the lean blend due to the low kinematic viscosity value because which the fuel can be easily atomized by injector for quick combustion in the cylinder and heat loss is reduced, increasing thermal efficiency when diesel and B10 lean blend of KOME is used as fuel.



Graph 6. Exhaust Gas Temperature

4.3.5. Oxides of Nitrogen:

The NO_x emission differs for diesel and biodiesels, similarly the comparison of NO_x emission for different blends of kapok methyl ester-diesel and diesel is measured and represented in graph7. The inference obtained from NO_x emission is that emission increases with increasing concentration of methyl ester in the fuel blend. It is observed that the NO_x emission of Biodiesels are higher than that of standard conventional diesel. At full load condition, diesel takes the least ppm count when compared to other blends of biodiesel. When the engine load is increased the temperature also increases gradually and temperature is important parameter in NO_x formation, with increase in concentration of KOME more than 50% can further lead to high NO_x emission. Generally the problem of NOx emission persist in almost all the Biodiesel produced and there are new, advanced recent techniques such as Exhaust gas recirculation and selective catalytic reduction which are used to reduce the exhaust gas temperature through which the reduction of NO_x emission achieved[17] .



Graph 7. Load Vs NO_x Emission

5. Conclusion:

The Engine test results were studied based on the Experimental project work of a single cylinder CI engine, with diesel and different blends of KOME-diesel, findings obtained from the test result are as follows: lean blend of KOME showed better performance characteristics (i.e) B10 blend showed a similar characteristic to that of diesel and was better when compared with other blends either in properties or in performance and emission characteristics also. The brake thermal efficiency decreased with increase in Biodiesel but B10 showed a comparable efficiency in Performance as well as emission analysis to the diesel performance and emission analysis. It is concluded that Blend B10 of Kapok methyl ester is effective alternate fuel for existing IC engines.

6. References:

1. Biofuel Promotion in India for Transport: Exploring the Grey Areas; The Energy and Resources Institute.
2. Government of India Ministry of New & Renewable Energy National Policy on Biofuels.
3. A Review of the National Biofuel Policy in India: A critique of the Need to Promote Alternative Feedstock's.
4. Prospects of 2nd generation biodiesel as a sustainable fuel— Part:1 selection of feedstock s ,oil extraction techniques and conversion technologies / Renewable and Sustainable Energy Reviews.
5. Progress and recent trends in biodiesel fuels; Energy Conversion and Management 50 (2009) 14–34.
6. A comprehensive review on biodiesel as an alternative energy resource and its characteristics; Renewable and Sustainable Energy Reviews 16 (2012) 2070–2093.
   Kapok oil methyl esters; Biomass and bioenergy(2014)1-7.
7. Catalytic cracking of edible and non-edible oils for the production of biofuels/Energy & Environmental Science/Energy Environ. Sci. , 2011, 4, 1087–1112.
8. Effective Conversion of Kapok Seed (Ceiba Pentandra) Oilinto Biodiesel and Investigation of Effects of Catalystconcentrations and Chromatographic Characterization; International Journal of ChemTech Research; CODEN (USA): IJCRGG ISSN : 0974-4290Vol.6, No.14, pp 5709-5715, Nov-Dec 2014
9. Production Of Biodiesel From Non Edible Ceiba Pentandra Seed Oil Having High Ffa Content; Arpn Journal Of Engineering And Applied Sciences; Issn 1819-6608.
10. Production and comparative fuel properties of biodiesel from non-edible oils: Jatropha curcas, Sterculia foetida and Ceiba pentandra; Energy Conversion and Management 73 (2013) 245–255.
11. Experimental investigation of kapok (Ceiba pentandra) oil biodiesel as an alternate fuel for diesel engine; Energy Conversion and Management 75 (2013) 773–779.

12. Experimental study on the performance and emission measures of direct injection diesel engine with Kapok methyl ester and its blends; Renewable Energy 74 (2015) 903-909.
13. Experimental study on performance and exhaust emissions of a diesel engine fuelled with Ceiba pentandra biodiesel blends; Energy Conversion and Management 76 (2013) 828–836.
14. Engine performance and emissions using Jatropha curcas, Ceiba pentandra and Calophyllum inophyllum biodiesel in a CI diesel engine; Energy (2014) 1e19.
15. Experimental Investigation On Performance And Emission Analysis Of Ci Engine Fuelled With Methyl Ester Of Silk Cotton Oil And Various Diesel Blends; Issn 2278 – 0149.
16. Performance and Emission Analysis of C.I.Engine with Kapok Methyl Ester and Its Blends; Advanced Materials Research Vol. 505 (2012) pp 458-462.

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