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Performance Test on the C.I Engine by using Different Biofuels

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ABSTRACT

On the face of the upcoming energy crisis, vegetable oils have come up as a promising source of fuel. They are being studied widely because of their abundant availability, renewable nature and better performance when used in engines. Many vegetable oils have been investigated in compression ignition engine by fuel modification or engine modification. The vegetable oils have very high density and viscosity, so we have used the methyl ester of the oil to overcome these problems. Their use in form of methyl esters in non-modified engines has given encouraging results.

Coconut oil (copra), Waste vegetable oil, Karanja oil (Pongamia Pinnata) is available abundantly in India. An experimental investigation was made to evaluate the performance characteristics and overall emissions of a diesel engine using different blends of these three methyl esters with mineral diesel. Methyl esters of these three oils were blended with diesel in proportions of 20% and 40% by mass and studied under various load conditions in a compression ignition (diesel) engine. The performance parameters were found to be very close to that of mineral diesel. The brake thermal efficiency and mechanical efficiency were better than mineral diesel for some specific blending ratios under certain loads. The emission characteristics were also studied and levels of carbon dioxide, carbon monoxide, nitric oxide and hydrocarbons were found to be higher than pure diesel.

Keywords: *Methyl esters of coconut oil, karanja and waste vegetable oil, transesterification, biodiesel, engine performance.*

I. INTRODUCTION

In 1911, Rudolf Diesel presented the world with the compression ignition engine, which at that time did not have a specific fuel. Diesel claimed that the engine could be fed by vegetable oils which could help the agricultural development in countries using this engine. Biodiesels are derived from vegetable oils or animal fats, more specifically the alkyl esters from these. The esters from vegetable oils are considered to be superior since they have a higher energetic yield and essentially no engine modifications are necessary for their use. Biodiesels have been traced back to the mid-1800s, where transesterification (described in Chapter 3) was used to make soap and the alkyl esters (biodiesels) were just considered byproducts. Early feedstocks were corn, peanut, hemp oils, and tallow.

The idea of using vegetable oils instead of fossil diesel fuels has resurfaced as a way to minimize the net carbon footprint left by emissions from compression ignition (CI) engines. Straight vegetable oils (SVOs) have their fair share of problems in unmodified CI engines. These problems include: cold-weather starting; plugging and gumming of filters lines, and injectors; engine knocking; coking of injectors on piston and head of engine; carbon deposits on piston and head of engine; excessive engine wear; and deterioration of engine lubricating oil. Vegetable oils decrease power output and thermal efficiency while leaving carbon deposits inside the cylinder. Most of these problems with vegetable oil are due to high viscosity, low cetane number, low flash point, and resulting incomplete combustion.

To avoid some of these problems, vegetable oils have been converted via a chemical process (transesterification) to result in a fuel more like fossil diesel. The resulting fuel is biodiesel, a biodegradable and nontoxic renewable fuel. Furthermore, biodiesels have reduced molecular weights (in relation to triglycerides), reduced viscosity, and improved volatility when compared to ordinary vegetable oils. Most CI engines can run on biodiesels without modifications; however to optimize combustion the injection timing should be adjusted. There may be some long term problems that are yet to be quantified along with large scale availability and related consequences on the agricultural sector. Overall, biodiesels have great potential and deserve more attention and use.

II. BIODIESELS

Vegetable oils contain a substantial amount of oxygen in their structure. The vegetable oils have about 10 percent less heating value than diesel oil, due to the oxygen content in their molecules. The kinematic viscosity is however, several times higher than that of diesel oil. Vegetable oils are extracted naturally by animal fats and also from plants. In recent years they are extremely used by the humans for mobilizing the vehicles. In this project we use waste vegetable oil, coconut oil and karanja oil as they are considered as vegetable oils.

2.1 Karanja Oil

Karanja Oil: It belongs to the family leguminaceae. Commonly known as Pongamia Pinnata. Other name of karanja oils are pongam oil or honge oil. Pongamia is widely distributed in tropical Asia. The tree is hardy, reasonably drought resistant and tolerant to salinity. It is attractive because it grows naturally through much of arid India, having very deep roots to reach water, and is one of the few crops well-suited to commercialization by India's large population of rural poor. The karanja tree is of medium size, reaching a height of 15-25 meters. The tree bears green pods which after some 10 months change to a tan color. The pods are flat to elliptic,5-7 cm long and contain 1 or 2 kidney shaped brownish red kernels. The yield of kernels per tree is reported between 8 and 24 kg. The composition of typical air dried kernels is : Moisture 19%, Oil 27.5%, Protein 17.4%. The oil content varies from 27% 39%. The most common method to extract oil involves in collecting the pods. The pods are kept in water for 2 to 3 hours followed by drying in hot atmospheric condition. The dried pods are stuck with hammers and sticks to open them after which the seeds are winnowed out. Oil extraction is carried out in Ghanis and small expellers. The oil is dark in color with a disagreeable odor.

Table No. 1: karanja oil fatty acid values in Percentage

S.No	Fatty acid	Value (%)
1.	Palmitic	3.7-7.9
2.	Stearic	2.4-8.9
3.	Oleic	44.5-71.3
4.	Linoleic	10.8-18.3
5.	Lignoceric	1.1-3.5

2.2. Extraction of Karanja Oil

For oil extraction from kernel of karanja two methods were implemented. First one was the mechanical extraction. The seeds were expelled in a mechanical expeller which was available in the Integrated Biodiesel Plant of OUAT. The oil recovery was calculated to be near about 27%. Second method used was Solvent extraction. Extraction was done with n-hexane using a Soxlet apparatus in the Renewable Energy Lab of OUAT. Process of solvent extraction was that in a nutshell, the extraction process consists of treating the raw material with hexane (solvent) and recovering the oil by distillation of the resulting solution of oil by distillation of the resulting solution of oil in hexane called miscella. Evaporation and condensation from the distillation of miscella recovers the hexane absorbed in the material. The hexane thus recovered was reused for extraction. The low boiling point of hexane (6700C) and the high solubility of oils and fats in it were the properties exploited in the solvent extraction process. Under this process the oil content was found to be 35% which is more than that of mechanical expeller.

Fig 4: Karanja oil

In order to reduce viscosity, four techniques were adopted like pyrolysis, dilution, micro emulsification and transesterification. Currently we adopt transesterification technique to convert high FFA and high viscous fluid to low FFA and low viscous fuel, namely karanja biodiesel. Since the crude karanja oil acid value was found to be more than 6, so acid esterification and transesterification techniques was adopted.This conversion to biodiesel was conducted in Renewable Energy Lab of OUAT, Bhubaneswar. All the chemicals needed were available in the lab. The alcohol used is methanol, acid is sulfuric acid and KOH is used as an alkali.

Fig 5: karanja oil constant heating

2.3. Transesterification of karanja oil:

Feed stocks containing less than 4% free fatty acids are filtered and preprocessed to remove water and contaminants and then fed directly to the transesterification process along with any products of the acid esterification process. The catalyst KOH is dissolved in methanol and then mixed with the pretreated (650C) oil. Once the reaction is complete, the major co-products, biodiesel and glycerin are separated into two layers. The product is allowed to stand overnight to separate the biodiesel and glycerol layer. The upper biodiesel layer is separated from the glycerol layer and washed with hot distilled water to remove the excess methanol, catalyst and traces of glycerol. The washed ester layer is dried under the vacuum to remove the moisture and methanol and again passed over a hydrous Na2SO4. The biodiesel obtained is termed as Karanja oil methyl ester (KOME).

Fig 6: Methnol collecting

layer. The upper biodiesel layer is separated from the glycerol layer and washed with hot distilled water to remove the excess methanol, catalyst and traces of glycerol. The washed ester layer is dried under the vacuum to remove the moisture and methanol and again passed over a hydrous Na2SO4. The biodiesel obtained is termed as Karanja oil methyl ester (KOME).

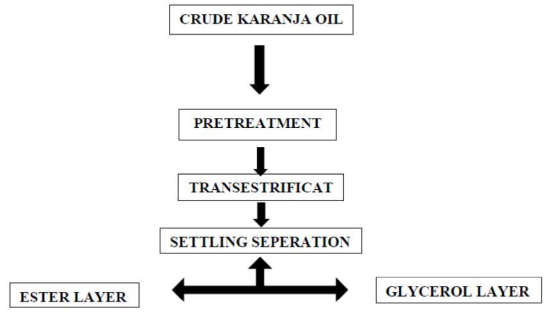

Fig 7: Extraction of Karanja Oil

2.4 Settling and Separation:

Once the reaction is complete, it is all owed for settling for 8-10 hours in separating funnel. At this stage two major products obtained that are glycerin and biodiesel. Each has a Substantial amount of the excess methanol that was used in the reaction. The glycerin phase is much denser than biodiesel phase and is is settled down while biodiesel floted up. The two can be gravity separated with glycerin simply drawn off the bottom of the settling vessel. The amount of trans esterified karanja biodiesel (KOME) and glycerin by this process are given in table-3.

Fig 8: Separation Of Karanja Oil

2.5 Karanja methyl ester Properties as per ASTM Standard:

Properties	Unit	Karaja (Methyl ester)	Diesel
Density	gm/cc	860	.840
Kinematic viscosity @ 40^0C	Cat	4.78	2.98
Acid value	mgKOH/gm	0.42	0.35
Flash point	^0C	144	74
Cetane number		41.7	49
Carbon residue	%	0.005	0.01
Ash content	%	0.005	0.002

Table No. 2: Comparison Of Karanja Oi

2.5 Coconut oil as Biodiesel:

Coconut oil is used in oil lamps, cooking, manufacturing, treatment for diseases. Coconut water (also called coconut juice) is the liquid found in the center of the coconut. It is not called coconut milk, which is something different. Coconut water is very healthy. It is naturally filtered and sterile. It contains many of the beneficial nutrients of coconut oil, such as lauric acid. It gives a natural energy boost, and is one of the best energy/sports drinks you can get. Coconut water is one of the highest sources of electrolytes known to man, and can be used to prevent dehydration.

Coconut milk is made by soaking the grated coconut meat in hot water or scalded milk, and then straining it. Coconut milk is classified as thick, thin, or coconut cream. Thick coconut milk is the result of the first soaking and squeezing. If this milk is refrigerated it separates, and the top layer is the cream. Thin coconut milk is what is produced when the coconut meat is soaked a second time and then strained and squeezed.

The process to turn coconuts into biodiesel starts with the meat, or copra, of the coconuts. The meat is grated, dried and then pressed to extract the coconut oil. Many Tongans, who have entire marriage rituals involving coconuts, are expert extractors and could use hand presses instead of diesel-powered ones if they want to cut costs. The oil is then mixed with two chemicals, methanol and sodium hydroxide, in the reactor for two hours to transition the oil into clean-burning fuel. The byproduct of the process, glycerol, can be made into soap or compost and sold along with the rest of the coconut husk and meat.

Fig 9: Separation of Coconut Methyl Ester

2.6. Waste Vegetable Oil As Biodiesel:

Vegetable oil is an alternative fuel for diesel engines and for heating oil burners. For engines designed to burn diesel fuel, the viscosity of vegetable oil must be lowered to allow for proper atomization of the fuel; otherwise incomplete combustion and carbon build up will ultimately damage the engine. Many enthusiasts refer to vegetable oil used as fuel as waste vegetable oil (WVO) if it is oil that was discarded from a restaurant or straight vegetable oil (SVO) or pure plant oil (PPO) to distinguish it from biodiesel.

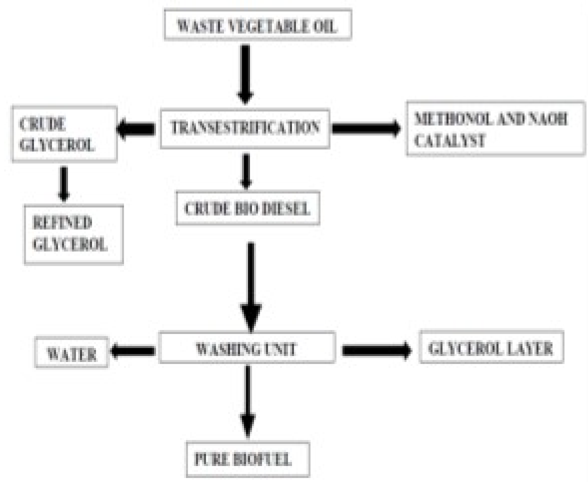

Fig 10: Transesterification of Vegetable Oil

3. Experimental Setup

A schematic diagram of the experimental set-up is shown in Figure 13. And the specifications are shown in Table 3.

Fig 11: Single cylinder four stroke diesel engine

3.1. Experimental Trail

Fig 12: Diesel Engine Set Up

The overall effectiveness of the various fuels in a 6 HP single-cylinder CI test engine is described here. The fuels to be tested in this engine are: Pure Diesel, WVO biodiesel, Coconut Oil, and karanja oil. The biodiesel samples will be 100% biodiesel (B100) and the straight vegetable oil (SVO) will also be 100%. The engine with a rope brake dynamometer is used to measure the power output, specific fuel consumption, Thermal characteristics, etc. for these fuels to provide an accurate means of comparing their performances. The engine has been instrumented with in-cylinder thermocouples for intake and exhaust gases, speed sensors, a weighted fuel tank, and an ASME nozzle for the air flow measurement. With these instruments Brake Specific Fuel Consumption (BSFC), Exhaust Temperature, Brake Horsepower (BHP), Mechanical Efficiency, Thermal Efficiency for varied loads could be determined.

3.2. Formulae to be used:

1. **Fuel consumption (F.C.)** =29.16/T kg/hr

$$F.C. = \frac{VOLUME}{TIME} \times DENSITY$$

2. Break Power (B.P) = $\frac{2\pi NT}{60}$

3. Indicated Power (I.P) = **B.P + F.P**

4. Friction power: This is calculated using Willian's line method. Gross fuel consumption vs B.P. at a constant speed are plotted and the graph was extrapolated back till zero fuel consumption. The point where this graph cuts the B.P. axis that gives friction power of the engine at that speed. This negative work represents the combined loss due to mechanical friction, pumping and blow by. It is taken from graph.

5. Efficiency $(\eta m) = break\ power/indicated \times 100$ **6. Indicated thermal efficiency** $= (\eta i) = IP \times \frac{3600}{FC \times Cv}$

4.3. RESULTS AND DISCUSSION

Table 5: Pure Diesel test

S.NO	LOAD		Time	N	F.C= 29.16t	B.P	F.P	I.P	ηm	ηi	Brake Thermal Efficiency
	KG	N									
1	0	0	80	1500	0.36	0	0.8	0.8	0	22	0
2	2	19.62	70	1500	0.42	0.5	0.8	1.3	38	30	10
3	4	39.24	60	1500	0.48	1.0	0.8	1.8	55	32	16
4	6	58.86	50	1500	0.58	1.5	0.8	2.3	65	33	20

Table 6: B20 of Karanja

S. NO	LOAD		Time taken	Speed N	F.C=29 .16t	B.P	F.P	I.P	ηm	ηi	Brake Thermal Efficiency
	KG	N									
1	0	0	78	1500	0.37	0	0.8	0.8	0	17	0
2	2	19.62	70	1500	0.41	0.5	0.8	1.3	38	26	10
3	4	39.24	65	1500	0.45	1.0	0.8	1.8	53	33	18
4	6	58.86	58	1500	0.5	1.5	0.8	2.3	63	38	24

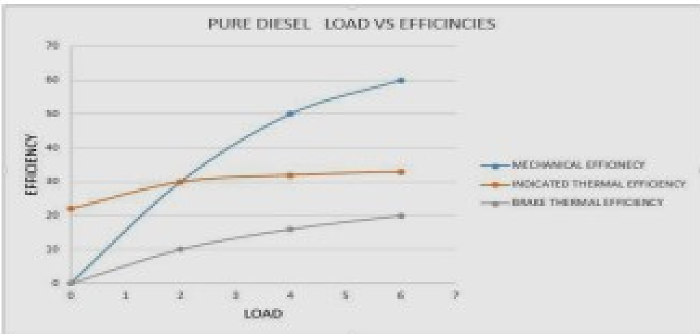

Fig 13: Effect of loads on diesel engine efficiency without using biodiesel

Fig 14: Effect of loads on diesel engine efficiency using B20 of Karanja biodiesel

Table 7: B 40 of Karanja

S.NO	LOAD		Time taken	N	F.C=29.16t	B.P	F.P	I.P	mechanical Efficiency(η)	Indicated Thermal Efficiency (η)	Brake Thermal Efficiency
	KG	N									
1	0	0	81	1500	0.36	0	1.15	1.15	0	26	0
2	2	19.62	78	1500	0.38	0.5	1.15	1.65	30	36	11
3	4	39.24	69	1500	0.42	1.0	1.15	2.15	46	43	20
4	6	58.86	59	1500	0.49	1.5	1.15	2.65	56	45	25

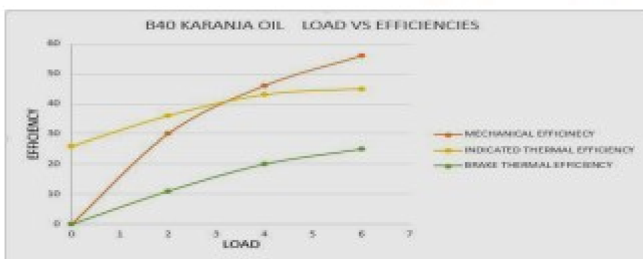

Fig 15: Effect of loads on diesel engine efficiency using B40 of Karanja biodiesel

Table 8: B-20 of coconut oil

S. NO	LOAD		Time taken for 10cc of fuel	Speed N	Consumption F.C=29.16t	B.P	F.P	I.P	mechanical Efficiency(η)	Indicated Thermal Efficiency (η)	Brake Thermal Efficiency
	KG	N									
1	0	0	72	1500	0.4	0	0.85	0.85	0	16	0
2	2	19.62	70	1500	0.42	0.5	0.85	1.35	37	25	09
3	4	39.24	62	1500	0.47	1.0	0.85	1.85	54	31	17
4	6	58.86	54	1500	0.54	1.5	0.85	2.35	64	35	22

Fig 16: Effect of loads on diesel engine efficiency using B-20 of coconut oil biodiesel

Table 9: B-40 of coconut oil

S. NO	LOAD		Time taken for 10cc of fuel	Speed N	Consumption F.C=29.16t	B.P	F.P	I.P	mechanical Efficiency (η)	Indicated Thermal Efficiency (η)	Brake Thermal Efficiency
	KG	N									
1	0	0	86	1500	1.43	0	0.85	0.85	0	25	0
2	2	19.62	82	1500	1.43	0.5	0.35	1.35	37	42	11
3	4	39.24	70	1500	1.3	1.0	0.85	1.85	54	45	19
4	6	58.86	58	1500	1.3	1.5	0.85	2.35	64	46	24

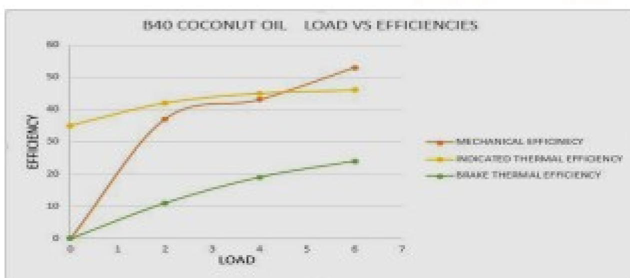

Fig 17: Effect of loads on diesel engine efficiency using B-40 of coconut oil biodiesel

Table 10: B-20 of waste vegetable oil

S. NO	LOAD		Time taken for 10cc of fuel	N	F.C=29.16t	B.P	F.P	I.P	η m	(η i)	Brake Thermal Efficiency
	KG	N									
1	0	0	80	1500	0.405	0	0.9	0.9	0	20	0
2	2	19.62	74	1500	.42	0.5	0.9	1.4	35	28	10
3	4	39.24	64	1500	0.47	1.0	0.9	1.9	52	34	18
4	6	58.86	56	1500	0.54	1.5	0.9	2.4	62	37	23

Fig 18: Effect of loads on diesel engine efficiency using B-20 of waste vegetable oil

Table 11: B-40 of waste vegetable oil

S.NO	LOAD		Time taken for 10cc of fuel	N	F.C=29.16t	B.P	F.P	I.P	ηi	ηm	Brake Thermal Efficiency
	KG	N									
1	0	0	92	1500	0.32	0	1.2	1.2	0	30.8	0
2	2	19.6	80	1500	.36	0.5	1.2	1.7	29	38	11
3	4	39.2	68	1500	0.43	1.0	1.2	2.2	45	42	19
4	6	58.8	56	1500	0.52	1.5	1.2	2.7	55	42.6	24

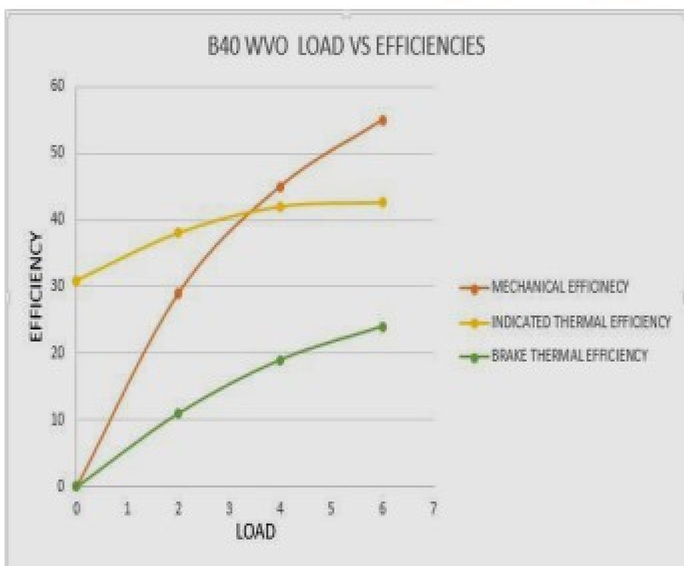

Fig 19: Effect of loads on diesel engine efficiency using B-40 of waste vegetable oil

4.11 Comparison of mechanical efficiencies between diesel and Three Biodiesels

Table 12: Comparison of Mechanical efficiencies

Bio diesel	Load	Diesel η_m	Karanja η_m	Coconut oil η_m	WVO η_m
B-20	2	38	36	37	35
	4	55	53	43	52
	6	65	63	64	62
B-40	2	38	36	37	29
	4	55	46	43	45
	6	65	56	53	55

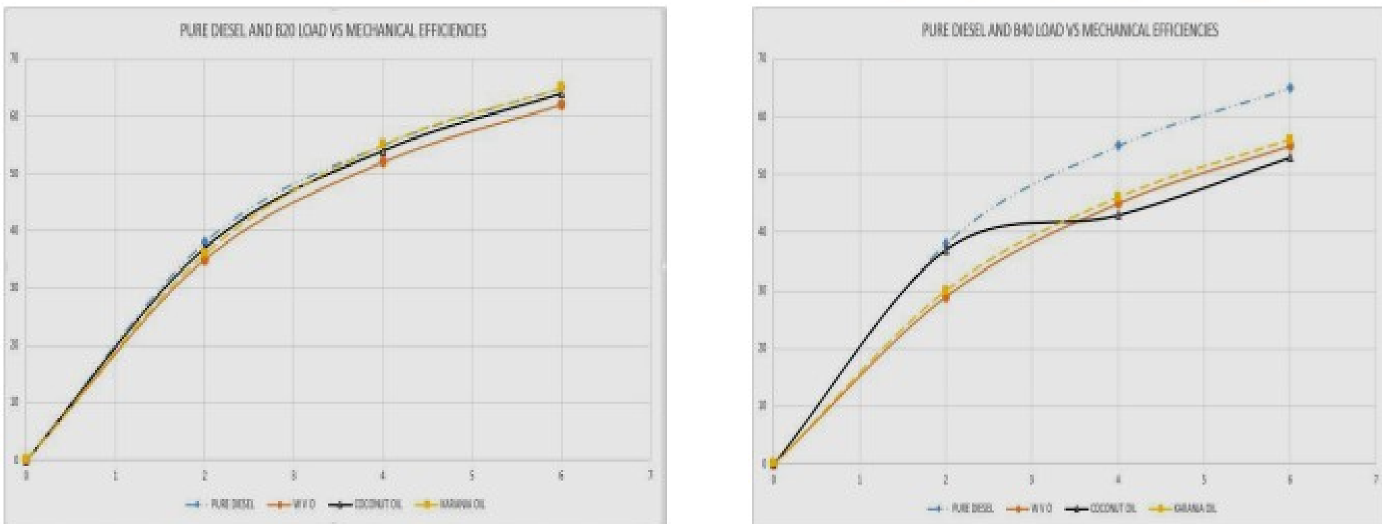

Fig 20 (a), (b): Effect of mechanical efficiency on diesel engine efficiency

4.12 Comparison of break thermal efficiencies between diesel and Three Biodiesels

Table 12: Comparison of break thermal efficiencies

Bio diesel	Load	Diesel η_m	Karanja η_m	Coconut oil η_m	WVO η_m
B-20	2	10	10	9	10
	4	16	18	17	18
	6	20	24	22	23
B-40	2	10	11	11	11
	4	16	20	19	19
	6	20	25	24	24

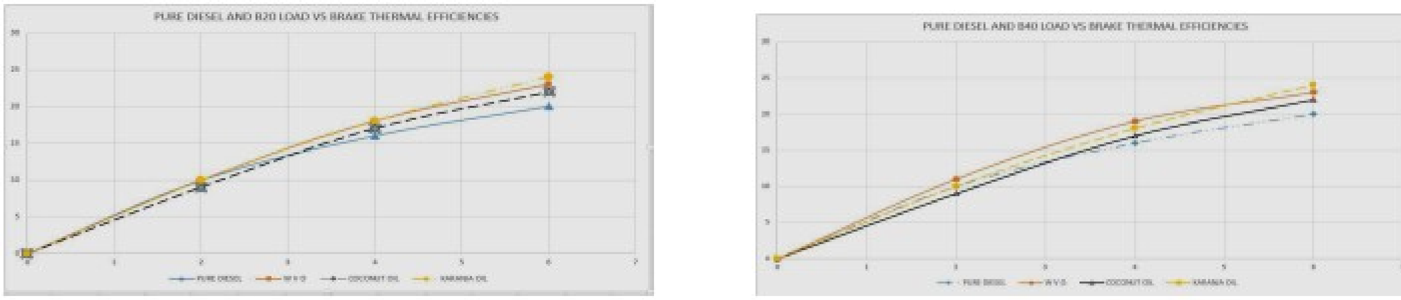

Fig 21 (a), (b): Effect of break thermal efficiency on diesel engine efficiency

4.13 Comparison of indicated thermal efficiencies between diesel and Three Biodiesels

Table 12: Comparison of indicated thermal efficiencies

Bio diesel	Load	Diesel η_m	Karanja η_m	Coconut oil η_m	WVO η_m
B-20	0	22	17	16	20
	2	30	26	25	28
	4	32	33	31	34
B-40	0	22	26	25	30.8
	2	30	36	42	38
	4	32	43	45	42

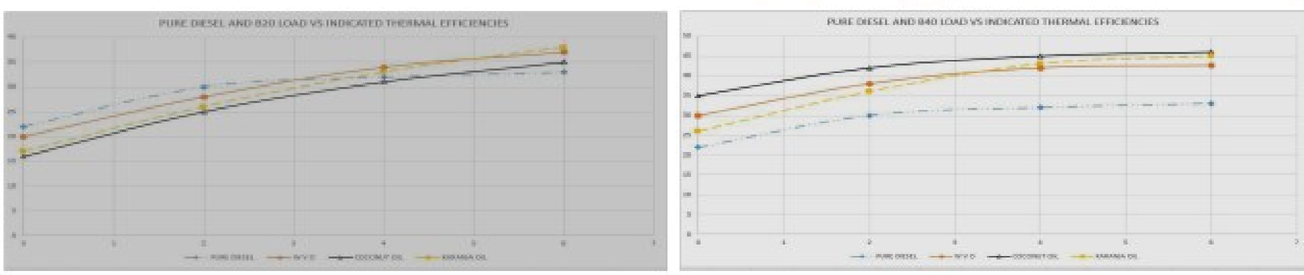

Fig 22 (a), (b): Effect of indicated thermal efficiency on diesel engine efficiency

CONCLUSIONS:

- In comparison to petroleum and gasoline, Biodiesel beats its competitors in all categories of toxic substance emissions and poses close to no threat to the environment also significantly reducing many health hazards.
- The fact that most biodiesels are domestically produced means that by using more of it, the market of biodiesel would actually stimulate the economy, reducing a country's dependence on foreign imports.
- Also, the implementation of biodiesel is extremely easy and requires little or no modifications to the typical diesel engine, making it a very easy and smooth transition.
- By testing our fuels we here by concluded that the properties of diesel are easily attained by biodiesel with easy methods. In most of Biodiesels carbon deposition is less and coconut oil have viscosity (2.3) equal to diesel (1.8-4) and karanja oil (24-25) has high brake thermal efficiency than to diesel (20).
- Many of the biodiesel has a positive impact on both the engine and environment. Engine has high brake thermal efficiency and low exhaust values. While coming to Nature it is renewable source of energy.

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