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Performance and Emission Analysis of Manila Tamarind and Custard Apple Seed Oil As Bio Diesel

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Abstract:
Demand and price of fuel is increasing day by day. This led to find an alternative fuels for internal combustion engines. Biodiesel production is worthy of continued study and optimization of production procedures because of its environmentally beneficial attributes and its renewable nature. Non- edible oils such as manila tamarind and custard apple oil, produced by seed-bearing shrubs, can provide an alternative and do not have competing food uses. Biodiesel was prepared from the Non-edible oil of manila tamarind and custard apple by transesterification of the raw oil with methanol in the presence of NaOH as catalyst. The experimental treatments of a 200ml methanol to oil, addition of 5%(by wt) catalyst, 65-70^{0}C reaction temperature using low quality crude manila tamarind and custard apple oil separately resulted in optimum yield in which the biodiesel content exceeded 95% at 2 hours. The resulting 50% manila tamarind oil and 50% custard apple oil is blended with diesel in different percentage. Performance and emission tests were carried out for 10%, 30%, and 50% manila tamarind and custard apple oil diesel blends. Results confirm that the performance and emission of the engine fuelled manila tamarind and custard apple oil biodiesel and their blend with diesel fuel is by and large comparable with pure diesel.

Keywords: Manila tamarind oil, Custard apple oil, Biodiesel, transesterification, Performance and Emission Test

1. INTRODUCTION

The world at present mainly dependent on petroleum based fuels for power generation. Since these fuel sources are depleting fast, it is foremost important to find alternative sources of fuel for power generation. Moreover the capacity production of power is very less compared to the demand and due to problem in transmission; it is a greater task to electrify all parts, especially the rural parts of most of the developing countries. A promising way to electrify the rural areas in the developing countries is developing decentralized power generating units for various operations like pumping, lighting etc. At this scenario, it is foremost important to work at the scope of the fuel sources available at the native areas as input for decentralized power generating units because the benefits of such transition would go immediately to the local community in terms of economy, employment, etc.

1.1 VEGETABLE OILS

In the last few years interest & activity has grown up around the globe to find a substitute of fossil fuel. According to Indian scenario the demand of petroleum product like diesel is increasing day by day hence there is a need to find a solution. The use of edible oil to produce biodiesel in India is not feasible in view of big gap in demand and supply of such oil. Under Indian condition only non-edible oil can be used as biodiesel which are produced in appreciable quantity and can be grown in large scale on non-cropped marginal lands and waste lands. Non-edible oils manila tamarind and custard apple and mahua contain 30% or more oil in their seed, fruit or nut. India has more than 300 species of trees, which produce oil bearing seeds Around 75 plant species which have 30% or more oil in their seeds/kernel, have been identified and listed. Traditionally the collection and selling of tree based oil seeds were generally carried out by poor people for use as fuel for lightning. Biodiesel has become more attractive because of its environmental benefits and fact that it is made up of renewable resources. Although short term test using vegetable oil showed promising results, longer tests led to injector coking, more engine deposits, ring sticking and thickening of the engine lubricant.

1.2 MANILA TAMARIND OIL

The Botanical name of this tree is Pithecellobium dulce. It originated from Mexico, then went to America, Central Asia and then to India. Although these trees have been seen all along the highways in India, no one knew about its culinary use. It resembles tamarind and it is widely called as Manila Tamarind. Its Tamil name is 'Kodukka Puli'; the word derived its meaning from 'Kodi-kai puli' or vined tamarind. It is commonly called as 'Madras Thorn' or 'Monkey Pod' in English and 'Jungle Jilebi'/ 'Vilayati Imli' in Hindi, In telugu it is called 'Seema Chintakayalu' in tamil they also call it 'Kona Puliyankai' In tamil, since the pods coil so the name 'Twisted Tamarind'.It is generally eaten from road side vendors, and only recently, I saw a vehicle full of Kodukapuli being sold in the Triplicane and North Madras areas and can you believe it what used to be lying on the streets or on the trees to be eaten freely was being sold at Rs 40 for half a kilo. Considered as intruding weed, if it grows in the residential area, the pod/pulp is widely used in the tanning industry. Pithecellobium dulce is a tree that reaches a height of about 10 to 15 m (33 to 49 ft). Its trunk is spiny and its leaves are bipinnate. Its flowers are greenish white in colour, fragrant and coiled. The flowers produce a pod which turns pink when ripe and opens to expose an edible pulp. The pulp contains black shiny seeds that are circular and flat. The seed is dispersed via birds that feed on the sweet pulp. The tree is drought resistant and can survive in dry lands from sea level to an elevation of 1,500 m (4,900 ft), making it suitable for cultivation as a street tree. Manila Tamarind is a sour edible fruit mostly used for cooking, but also contains high nutritional value and numerous health benefits to the body. Pithecellobium Dulce is a leguminous tree came from an indigenous family of Fabaceae. This plant can be usually found in tropical climate countries including the Philippines. It is very popular worldwide, because of its unique taste and nutritional value. This leguminous tree is a multi-purpose tree producing edible and incandescent pods, which has red-pinkish to greenish-brown color. Its fruit usually consumed raw, cooked, or processed, while the oil extracted from the seeds can be used in making soap. Its fruit is mostly used for culinary purposes as an ingredient in some of our favorite dishes such as the popular Filipino dish called "Sinigang Sa Sampalok." It is also used in making some candy, pastries, and desserts. It has been also traditionally used by ancient people in treating and preventing numerous types of diseases, because of its medicinal properties. Aside from being an effective natural remedy, it is also more affordable compared to high-cost treatments and medications in the hospitals and medical centers. It contains vitamins A, B, C, E, K, niacin, thiamin, pantothenic acid, folate, riboflavin, carotene, pyridoxine, and dietary fiber. It also contains minerals including iron, phosphorus, calcium, manganese, magnesium, copper, zinc, potassium, sodium, and selenium.

1.2.1 Culinary uses of Manila Tamarind

The pods contain a sweet and sour pulp it is eaten raw as an accompaniment to various meat dishes and used as a base for drinks with sugar and water in Mexico. The seeds are also edible and refined to extract oil, which amounts for 10% of their weight. They also contain 28% protein. Many recipes can be prepared with Manila Tamarind like Manila Tamarind puli kuzhambu, Usili, chutney and curry.

1.2.2 Manila Tamarind as medicine

An extract of the leaves is used for gall bladder ailments and to prevent miscarriage. The ground seed is used to cleanse ulcers. Depending on the region of its occurrence pithecellobium is known by different names. In India it goes by the name "Madras thorn", although it is not native to Madras. The name "Manila tamarind" is also misleading, since it is neither closely related to tamarind, nor native to Manila.

1.2.3 Interesting facts

Kodukka puli came from the word Kodi-Kai puli which means Vined Tamarind

- peel the black seeds to reveal a brown coating (not the white 'main' seed inside) and then string them into bracelets
- The pod/pulp is widely used in the tanning industry. Camachile bark used almost exclusively by Filipino tanners
- Used as good timber
- Mucilaginous gum
- Used for preparing yellow dye

1.2.4 Health Benefits

- Used to treat Venereal diseases(Sexually Transmitted Infection)
- Leaves - Remedy for indigestion
- Bark - curative for bowel movement/constipation
- Camachile is also prescribed for diabetics

1.2.5 Health Benefits of Manila Tamarind

The bark and pulp being astringent and haemostatic, are used for a wide range of treatments. Bark extracts are used for chronic diarrhea, dysentery and tuberculosis. An extract of the leaves is used to prevent spontaneous abortion and for gall bladder ailments. Ground seed is used for ulcers. The leaves of the tree are used to treat certain conditions. They are used to treat both open and closed wounds. The pulp and bark are also used to treat tooth gum ailments, toothache and bleeding.

- **Flavor and Taste** The fruit is sweet to taste, musky and acidic, simply resembling desicated coconut, with a flavor that varies considerably, the flesh of the fruit melts on the tongue and it has a chewy, doughy, wispy and mildly grainy texture. Just like tamarind, the fruit has a shiny black seed surrounding the flesh, but they are not edible. Of the two types of fruit, the red-fleshly option is sweeter, while the white fruits may cause mild throat irritation
- **Storing Manila Tamarind** In view of the fact that, they are highly perishable, it is good to consume immediately. The white aril when peeled becomes brown. However with room temperature they will retain their freshness for three to four days.
- **Climate and Soil** The tree is best grown in tropical climates and has the capability to tolerate exceedingly hot conditions above 40°C; on the other hand, it can also tolerate a cold condition that is less than 5°C provided it is not long-drawn-out. Coming to the soil part, it can tolerate a great diversity of soil types, however does well in deep, well drained soils. It cannot withstand cold and wet soil. They are drought tolerant.

Figure 1.1 (a) Manila Tamarind fruit

Figure 1.1 (b) Manila Tamarind Tree and Manila Tamarind Seed

1.3 CUSTARD APPLE OIL

Custard apple is one of the Annona species of small trees or shrubs of the Annonaceae family, native to the New World tropics and Florida, or their fruits. The fruit of the common custard apple (Annona Squamosa), also called sugar apple or bullock's-heart in the West Indies, is dark brown in colour and marked with depressions giving it a quilted appearance; its pulp is reddish yellow, sweetish, and very soft (hence the common name); the kernels of the seeds are said to be poisonous. In India Custard apple is cultivated in Maharashtra, Andhra Pradesh, Karnataka, Bihar, Orissa and Tamilnadu. According to an estimate made by Indian Council of

Agricultural Research (ICAR), custard apple trees are grown in about 40,000hectares and can yield about 4 lakh tones seeds. This in turn can yields 1.12 lakh tones oil. It had also been known as sweetsop and sugar apple (English), seetaaphala (Tamil) and amritaphala (Kannada), Atoa and shariffa (Hindi). The present work is focused on the performance, combustion and emission characteristics of custard apple seed oil by using different types blends with diesel to find its suitability as fuel for CI engine. It is erect, with a rounded or spreading crown and trunk 10 to 14 in (25-35 cm) thick. The custard apple is believed to be a native of the West Indies but it was carried in early times through Central America to southern Mexico. It has long been cultivated and naturalized as far south as Peru and Brazil. It is commonly grown in the Bahamas and occasionally in Bermuda and southern Florida. Apparently it was introduced into tropical Africa early in the 17th century and it is grown in South Africa as a dooryard fruit tree. In India the tree is cultivated, especially around Calcutta, and runs wild in many areas. Figure 1.3 (a) shows the custard apple fruit. The fruit is greenish in color and contains 20-30 seeds in each fruit.

Figure 1.2 (a) Custard apple fruit

Figure 1.2 (b) Custard apple Tree and Custard apple Seed

Custard apple is known as a shrub or tropical branched tree which is native to the Amazon rainforest. This actually grows about three meters by up to eight meters in length. Its flowers are somewhat yellowish or greenish and its leaves are oblong and thin. Moreover, it comes with a lumpy and purple skin; it is described as a conical type of fruit and tastes very sweet. It can be used for sherbets, ice creams and milkshakes or you may also eat it fresh. Meanwhile, the fruit is creamy white, quite juicy and appears like a huge raspberry. Custard apple is widely known as Shariffa in the land of India.The custard apple tree is not sensitive and does not necessitate much care particularly if it is watered regularly and of course if it is provided with adequate light for it to grow. This tree has certainly adjusted to any type of soil and it grows fine, even in dry and hot climates. Once you have sowed the seeds, this will then bear fruits in about two up to three years. Its fruits are commonly round or conical in shape and will ripen for approximately three up to four months.

2. EXPERIMENTATION

2.1 EXTRACTION OF OIL:

In this experimentation process manila tamarind and custard apple oil seeds are collected in the plant after 3-4 days dry the seed using sunlight. The seed husk is removed completely and seeds can put into the jaw action bucket crushers. The manila tamarind and custard apple oil is collected in the bucket.

Figure 2.1 Manila Tamarind and Custard Apple oil Seed crushing machine

2.2 BIODIESEL PREPARATION

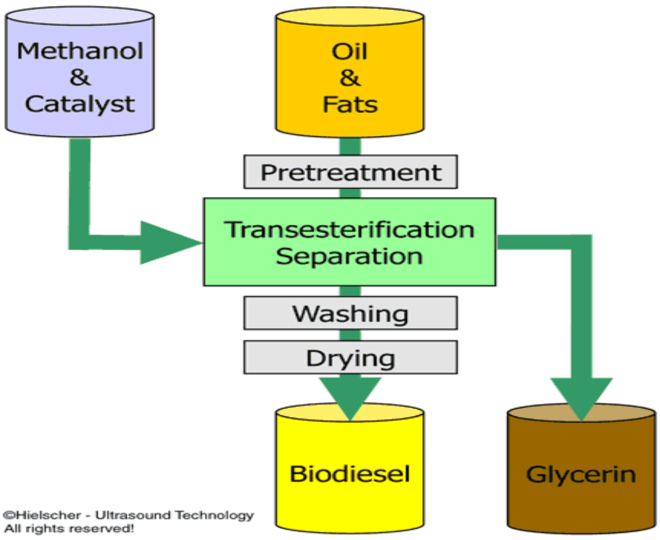
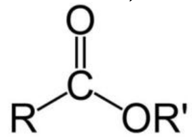


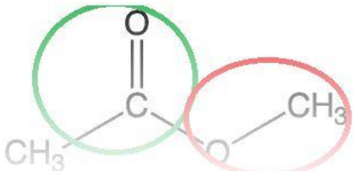
Figure 2.2 Flow Chart of Biodiesel Preparation

2.2.1 Esterification

If you were out playing basketball and rolled your ankle, you may take aspirin to relieve the pain and swelling. Aspirin relieves swelling and pain with a compound called salicylic acid, yet the carboxylic group in salicylic acid greatly irritates the stomach. Chemists discovered that if it is combined with acetic acid then it forms an ester, acetylsalicylic acid, which reduces the irritation on the stomach. This is the compound that we take as aspirin. The reaction that combined the salicylic acid and acetic acid to form acetylsalicylic acid is called esterification. **Esterification** is the process of forming esters from carboxylic acids. An **ester** is when a carbon is connected to two oxygens, but one of the oxygens isn't connected to anything else (so it is double-bonded to the carbon), while the other oxygen is connected to another carbon. Here is the general formula for an ester ('R' refers to a carbon chain)



A **carboxylic acid** is very similar to an ester, except the second oxygen is not connected to another carbon; it is just connected to a hydrogen atom. An **alcohol** is a carbon that is connected to an -OH group (or oxygen connected to hydrogen). Esterification occurs when a carboxylic acid reacts with an alcohol. This reaction can only occur in the presence of an acid catalyst and heat. It takes a lot of energy to remove the -OH from the carboxylic acid, so a catalyst and heat are needed to produce the necessary energy. Once the -OH has been removed, the hydrogen on the alcohol can be removed and that oxygen can be connected to the carbon. Because the oxygen was already connected to a carbon, it is now connected to a carbon on both sides, and an ester is formed.



The methyl acetate that was formed is an ester. In this image, the green circle represents what was the carboxylic acid (in this case acetic acid), and the red circle represents what was the alcohol (in this case methanol) This reaction lost an –OH from the carboxylic acid and hydrogen from the alcohol. These two also combine to from water. So any esterification reaction will also from water as a side product.

2.2.2 Transesterification

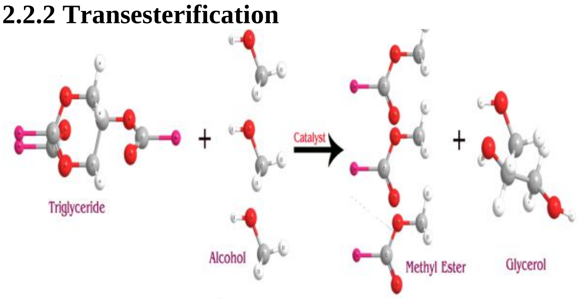


Figure 2.3 Transesterification process

Table 2.1 Properties of Manila Tamarind blended Custard Apple Oil

S.No	PARAMETERS	RESULT OBTAINED	DIESEL
1.	Flash point by PMCC	130 °C	52 °C
2.	Fire point by PMCC	140 °C	56 °C
3.	Kinematic viscosity @ 40°C	5.14 cst	2.60 cst
4.	Density @15°C	0.8780 gm/ml	0.850 gm/ml
5.	Gross calorific value	8973 Kcal/kg	4392 Kcal/kg
6.	Conrad son carbon residue	0.13 %	0.17 %
7.	Ash content	0.01%	0.01%

3. PERFORMANCE AND EMISSION TEST

3.1 Internal combustion research engine

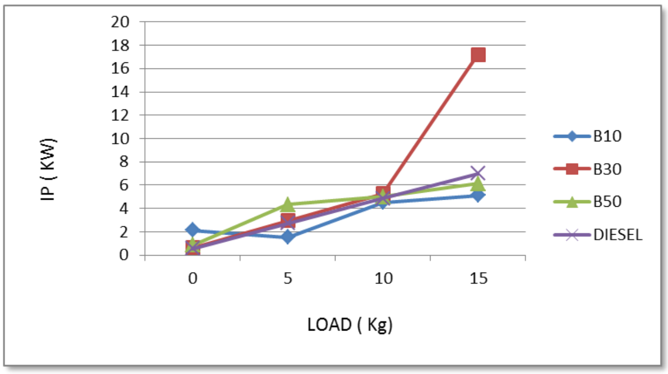
The performance tests were carried out in IC research engine for various proportions of MCME oil diesel blends.

3.2 Data collection

There are four test fuels were used during performance test includes 100 % diesel, 10 % MCME blend with diesel, 30% MCME blend with diesel, 50 % MCME blend with diesel. The following tables shows the obtained data's from performance tests for various MCME Diesel blends such as Brake power, Indicated power, brake mean effective pressure, indicated mean effective pressure, brake thermal efficiency, indicated thermal efficiency, mechanical efficiency, volumetric efficiency, specific fuel consumption, air flow, fuel flow and air fuel ratio

Table 3.1 Indicated power for various MCME Diesel blend

LOAD (kg)	INDICATED POWER (kW)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	2.11	0.62	0.85	0.54
5	1.52	2.95	4.34	2.72
10	4.50	5.26	5.02	4.86
15	5.12	17.21	6.13	7.00

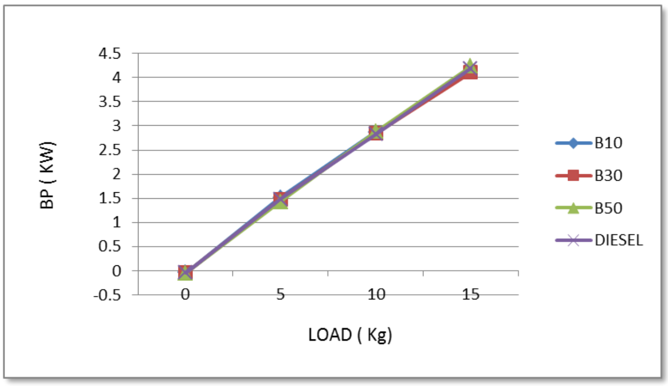


This graph shows how the indicated power is varies for 10 %, 30 %, 50% Manila Tamarind and Custard apple methyl ester diesel blends and pure diesel. Indicated power for diesel at 15kg is 7 kW. Indicated power for 10 %, 30 %, and 50 % of

Manila Tamarind and Custard apple methyl ester diesel blend is 5.12, 17.21, and 6.13 kW respectively. It clear that indicated power is decreases if the MCME percentage in fuel is increased.

Table 3.2 Brake power for various MCME Diesel blend

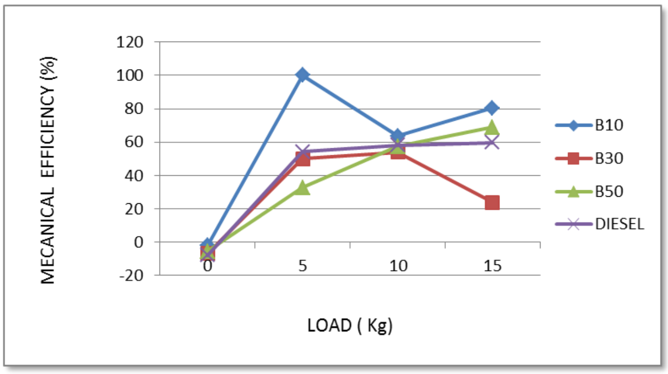
LOAD (kg)	BRAKE POWER (kW)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	-0.04	-0.04	-0.05	-0.04
5	1.52	1.48	1.43	1.48
10	2.87	2.84	2.88	2.83
15	4.12	4.11	4.23	4.19



This shows how the brake power is varies for 10 %, 30 %, 50% Manila Tamarind and Custard apple methyl ester diesel blends and pure diesel. Brake power for diesel at 15kg is 4.19 kW. Indicated power for 10 %, 30 %, and 50 % of Manila Tamarind and Custard apple methyl ester diesel blend is 4.12, 4.11, and 4.23 kW respectively. It is observed that brake power for different blends is higher as compared to pure diesel.

Table 3.3 Mechanical efficiency for various MCME Diesel blends

LOAD (kg)	MECHANICAL EFFICIENCY (%)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	-1.98	-6.85	-5.48	-7.86
5	100.09	50.02	32.83	54.32
10	63.77	53.91	57.31	58.29
15	80.42	23.89	68.98	59.77



It is observed that for all MCME diesel blends mechanical efficiency is higher when compared to pure diesel. It is also observed that the mechanical efficiency is decreased from 80.42 to 23.89 % for 30 % MCME diesel blend from 10 % MCME diesel blend and again it is increased to 68.98 % for 50 % MCME diesel blend.

Table 3.4 Brake mean effective pressure for various MCME Diesel blends

LOAD (kg)	BRAKE MEAN EFFECTIVE PRESSURE (%)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	-0.05	-0.05	-0.06	-0.05
5	1.85	1.79	1.73	1.78
10	3.51	3.47	3.54	3.46
15	5.13	5.10	5.25	5.19

The variation of brake mean effective pressure for various MCME diesel blend and pure diesel is shown in figure. Mean effective pressure for pure diesel at 15kg load is 5.19 bar. The same for 10 %, 30 %, and 50 % MCME diesel blends are 5.13, 5.15, and 5.25 bar respectively. It is observed that for 50 %MCME brake mean effective pressure is higher as compared to diesel after that it is decreases for 10 % and 30 % MCME gradually.

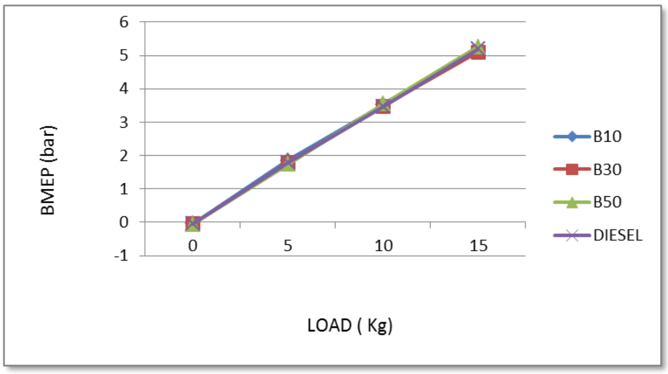
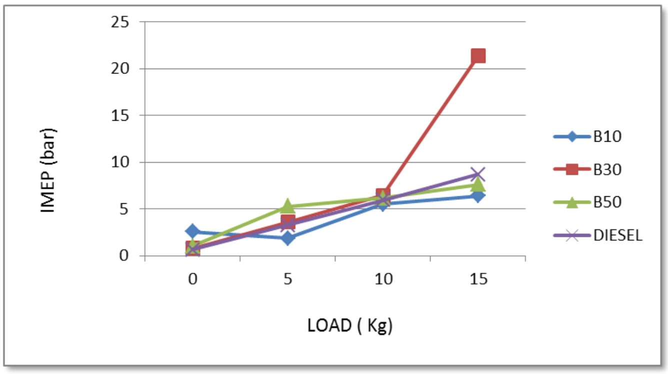


Table 3.5 Indicated mean effective pressure for various MCME Diesel blends

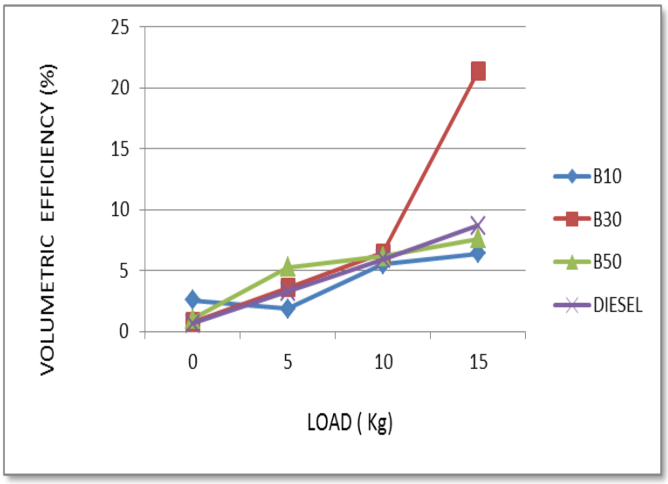
LOAD (kg)	INDICATED MEAN EFFECTIVE PRESSURE (kW)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	2.54	0.76	1.03	0.64
5	1.84	3.58	5.28	3.27
10	5.50	6.44	6.17	5.94
15	6.37	21.37	7.60	8.68



The variation of indicated mean effective pressure for various MCME diesel blend and pure diesel is shown in figure. Indicated mean effective pressure for pure diesel at 15kg load is 8.68 bar. The same for 10 %, 30 %, and 50 % MCME diesel blends are 6.37, 21.37, and 7.60 bar respectively. It is observed that indicated mean effective pressure is decreases if MCME diesel blend is increases.

Table 3.6 Volumetric efficiency for various MCME Diesel blends

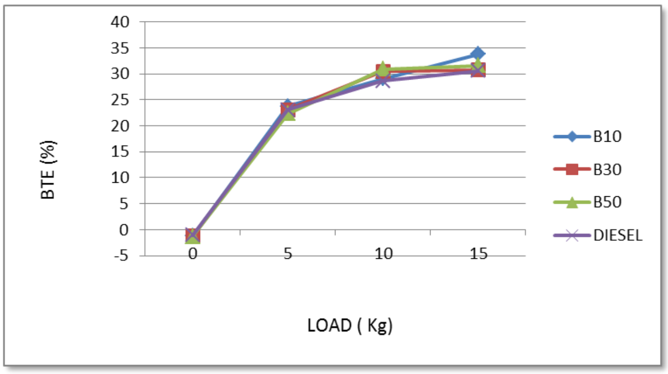
LOAD (kg)	VOLUMETRIC EFFICIENCY (%)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	78.39	78.94	78.76	79.03
5	78.51	78.27	78.12	78.13
10	77.17	77.20	77.55	77.14
15	76.37	76.30	76.01	75.89



The variation of volumetric efficiency with load is shown in Figure. It can be observed from the figure that the volumetric efficiency is 75.89 % at 15kg for diesel. However when the engine is fuelled with MCME-diesel blends such as 10% MCME, 30% MCME, and 50% MCME, It gives the volumetric efficiency of 76.37%, 76.30% and 76.01%, respectively at full load. It is observed that the volumetric efficiency of the Manila Tamarind and Custard apple methyl ester blend is closer or slightly higher to diesel except 10 % MCME diesel blend.

Table 3.7 Brake thermal efficiency for various MCME Diesel blends

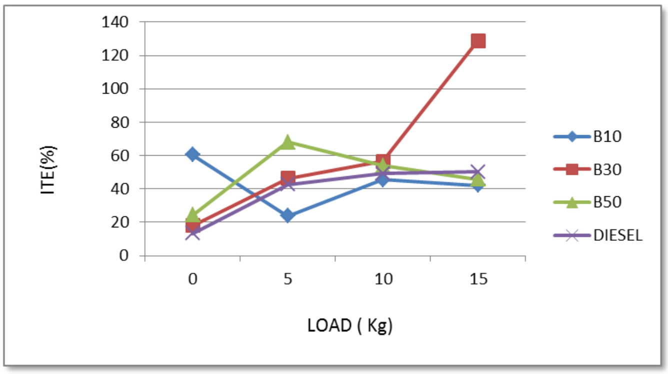
LOAD (kg)	BRAKE THERMAL EFFICIENCY (%)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	-1.20	-1.23	-1.33	-1.04
5	23.78	23.08	22.30	23.11
10	29.04	30.51	30.93	28.68
15	33.77	30.76	31.63	30.56



The variation of brake thermal efficiency with load is shown in Figure. It can be observed from the figure that the thermal efficiency is 30.56% at 15kg load for diesel. However when the engine is fuelled with MCME-diesel blends such as 10% MCME, 30% MCME, 50% MCME, it gives the thermal efficiency of 33.77%, 30.76%, 31.63%, respectively at 15kg load. It is also observed that brake thermal efficiency is higher for 10% and 50% MCME Diesel blends and it is slightly lower for 30 % MCME Diesel blend when compared to pure diesel.

Table 3.8 Indicated thermal efficiency for various MCME Diesel blends

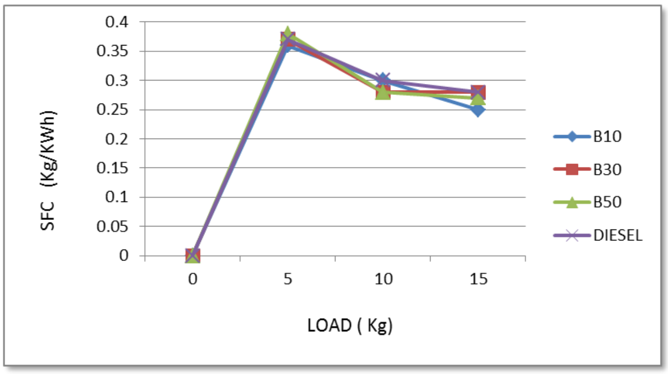
LOAD (kg)	INDICATED THERMAL EFFICIENCY (%)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	60.50	17.92	24.27	13.17
5	23.76	46.14	67.93	42.53
10	45.54	56.60	53.96	49.21
15	41.99	128.78	45.86	50.2



The variation of indicated thermal efficiency with load is shown in Figure. It can be observed from the figure that the indicated thermal efficiency is 25.2 % at 15kg load for diesel. When the engine is fueled with MCME diesel blends such as 10% MCME, 30% MCME, and 50% MCME, it gives the thermal efficiency of 41.99%, 128.78%, and 45.86% respectively at 15 kg load. It is also observed that indicated thermal efficiency is also higher for 30% and 50% blends and it is slightly lower for 10% MCME Diesel blend when compared to pure diesel.

Table 3.9 Specific fuel consumption for various MCME Diesel blends

LOAD (kg)	SPECIFIC FUEL CONSUMPTION (kg/kWh)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	0.00	0.00	0.00	0.00
5	0.36	0.37	0.38	0.37
10	0.30	0.28	0.28	0.30
15	0.25	0.28	0.27	0.28



The variation of specific fuel consumption with load is shown in Figure. It can be observed from the figure that the specific fuel consumption is 0.28kg/kWh at 15kg load for diesel. When the engine is fueled with MCME diesel blends such as 10% MCME, 30% MCME and 50% MCME, its specific fuel consumption is 0.25 and 0.28 kg/kWh, and 0.27 kg/kWh respectively at 15kg load. It is also noted that the specific fuel consumption is decreased for 10 % and 30% MCME Diesel blends and it is equal for 50 % MCME Diesel blend when compared to diesel.

4. EMISSION TEST

Table 4.1 carbon monoxide (CO) for various MCME Diesel blends

LOAD (kg)	CARBON MONOXIDE (CO)(% BY VOLUME)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	0.07	0.06	0.05	0.09
5	0.07	0.08	0.05	0.09
10	0.08	0.09	0.08	0.07
15	0.10	0.12	0.12	0.12

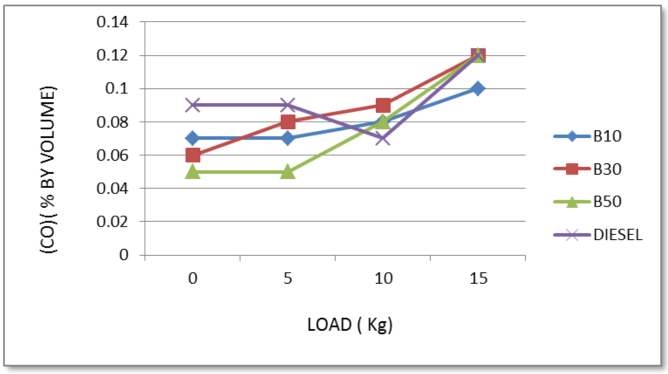


Table 4.2 hydrocarbons (HC) for various MCME Diesel blends

LOAD (kg)	HYDROCARBONS (HC) (ppm)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	47	56	57	35
5	52	62	60	70
10	57	61	61	83
15	61	67	67	100

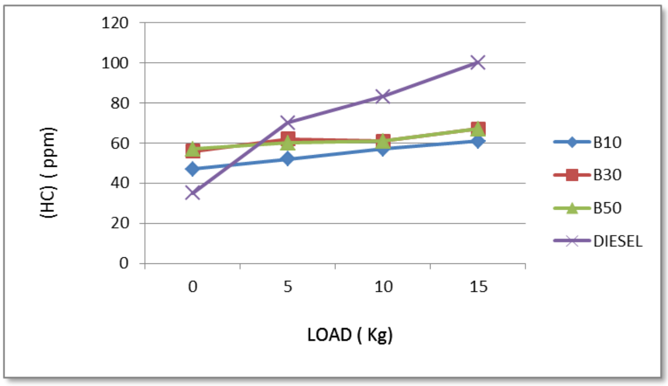


Table 4.3 Carbon dioxide (co_2) for various MCME Diesel blends

LOAD (kg)	CARBON DIOXIDE (CO_2) (% BY VOLUME)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	2.90	2.40	2.60	2.40
5	3.20	3.60	3.40	3.20
10	3.40	5.10	4.20	3.90
15	4.20	6.30	5.10	6.40

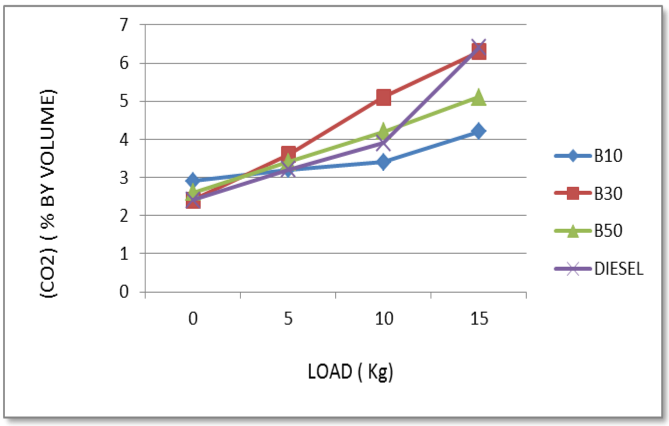


Table 4.4 Oxygen (O_2) for various MCME Diesel blends

LOAD (kg)	OXYGEN (O_2) (% BY VOLUME)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	16.50	16.10	16.90	18.26
5	13.32	15.70	15.14	17.04
10	14.12	14.41	19.72	15.04
15	13.02	13.10	13.10	14.81

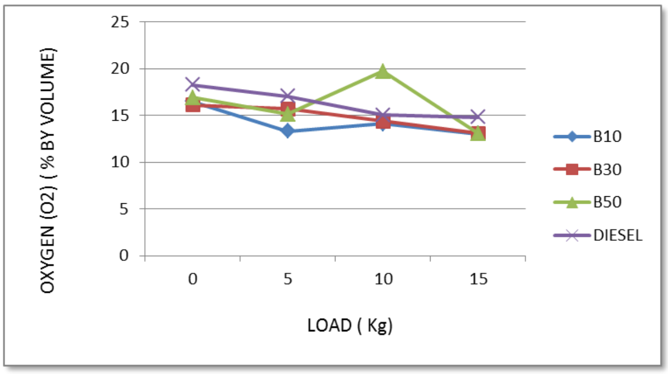
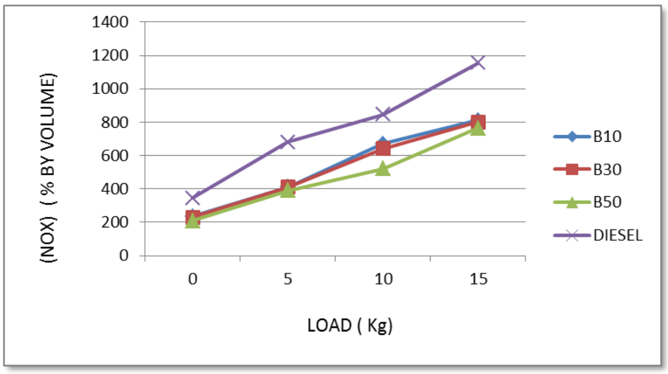


Table 4.5 Nitrogen oxide (NO_X) for various MCME Diesel blends

LOAD (kg)	NITROGEN OXIDE (NO_X) (% BY VOLUME)			
	10 %MCME Diesel blend	30 %MCME Diesel blend	50 %MCME Diesel blend	Diesel
0	234	230	209	346
5	410	410	389	680
10	670	640	520	845
15	812	801	763	1154



5. CONCLUSION

Bio-diesel has attracted much research because of its economic and environmental benefits as well as its renewable origin. Bio-diesel produced from non-edible oil resources can defy the use of edible oil for Bio-diesel production. Therefore, its demand is growing steadily, and researchers are lucking for possible newer sources of nonedible oil. This review concludes that non-edible oil is a promising source that can sustain Bio-diesel growth.

- Engine was able to run with B50 waste Manila Tamarind and Custard apple oil-diesel blend.
- Engine fuelled with B25 waste Manila Tamarind and Custard apple oil-diesel blend exhibits higher brake power (4.23 kW) when compared to pure diesel (4.19 kW).
- Mechanical efficiency (80.42 %) is higher for B20 waste Manila Tamarind and Custard apple oil-diesel blend when compared to pure diesel (59.77%).
- Hence a blend of B10 biodiesel and B30 diesel is recommended. There was no significant change in efficiency.
- Emission level is less when compare to the pure diesel. Especially B10 and B30 MCME diesel blends.

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