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NON-EDIBLE KUSUM OIL: POTENTIAL FOLIAGE OF BIODIESEL PRODUCTION AND ITS PRODUCTIVE USE IN MARINE ENGINES

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ABSTRACT

Biodiesel from non-edible vegetable oils is of paramount significance in India due to insufficient edible oil production. The use of biodiesel has been widely accepted as an effective solution to reduce greenhouse emissions. The high potential of biodiesel in terms of PM, NO_x, CO and CO_2 emission reduction may represent an additional motivation for its wide use. However the poor low temperature operability is imperative. According to these observations a different behaviour of the after treatment system, especially as far as control issues of the Diesel Particulate Filter are concerned is also expected. The use of biodiesel as alternative to fossil fuel for light duty CI engines to reduce greenhouse gas emissions was widely investigated. However, poor stability of biodiesel - diesel mixture limits the use of biodiesel to low volume concentrations. This paper presents the results concerning the use of a novel fuel additive package containing, pour-point depressant with the aim to increase the quality and amount of biodiesel in the diesel-biodiesel blends. In the above context Kusum oil methyl ester was blended with 10%, 20% ethanol and 10% ethanol diesel (each) to investigate the engine performance and emission characteristics. Result revealed Kusum oil methyl ester blended with 20% ethanol can be fuelled to marine diesel engines without any modification in engine hardware in spite of a negligible power loss.

KEYWORDS: KOME: Kusum Oil Methyl Esters, KOMEE20: 80% Kusum Oil Methyl Ester And 20% Ethanol, KOMEE10 D10: 80% Kusum Oil Methyl Ester Blended With 10%Ethanol And 10% Diesel, KOME E10: 90% Kusum Oil Methyl Ester And 10% Ethanol, CKO: Crude Kusum Oil, TEO: Transesterified Oil, FFA: Free Fatty Acids, FAME: Fatty Acid Methyl Ester, RKO: Refined Kusum Oil

INTRODUCTION

Kusum is widely available in sub-Himalayan region, Chhattishgarh, throughout central and southern India, Burma, Ceylon, Java and Timor. The plant, which is also commonly known as Ceylon oak, lac tree, or Macassar oil tree, belongs to the Sapindaceae family [1]. The *Schleichera* family is named after J. C. Schleicher, a Swiss botanist, and the species name means "oily" or "rich in oil [2]. The tree is native to India and Pakistan, but is also found in some parts of South East Asia. Schlichera Oliosa seed kernels contain 40.3% of yellowish brown coloured oil [3]. The potential of Kusum oil is around 66, 000 tonnes per year in India, out of which 4 000 to 5 000 tonnes are collected. It is a medium to large sized, evergreen, dense tree growing to 35 to 45 feet in height. It mainly occurs in sub-Himalayan tracts in the north and central parts of eastern India. The flowers come from February to April and yields fruit in June and July. The one or two almost round seeds some 1.5 cm in diameter and weighing between 0.5 and 1.0 g. The weight of 1000 seeds is 500-

700 g. Kusum seeds collected from tribal peoples of kalahandi district of odisha(India) were crushed in a mechanical expeller in the laboratory to extract Kusum oil (*Schleicheraoleosa*) for present study. Figure 1 shows Kusum tree bearing fruits.

Figure 1: Kusum Tree Bearing Fruits

FFA composition shows 16 components such as Myristic acid, Palmitic acid, Palmitoleic acid, Oleic acid, Linoleidic acid, Cis Linoleic acid, alpha-Linolenic acid, Eicosenoic acid, Eicosadienoic acid, Heneicosanoic acid, Behenic acid, Erucic acid, Lignoceric acid and Docosahexaenoic acid [4]. Alkaline-catalyzed esterification process could not produce biodiesel from high FFA oils from seeds of Kusum. A two-step esterification method is developed to produce biodiesel from Kusum, a high FFA non-edible vegetable oil. The acid-catalyzed pre-treatment process reduces the high FFA content of the crude oil to about 2% FFA. In second stage, oil is transesterified using alkaline catalyst. The fatty acid composition was investigated by GC/MS after methylation. The flash point of biodiesel is higher than that of diesel but viscosity and density are found to be close to that of diesel. The performance of the biodiesel can be improved if the concentration of esters in biodiesel is lower.

Although, during the last decade ethanol and biodiesel became the best known liquid bio fuels, numerous studies [5, 6] examine different chemical structures as possible bio-fuels and record their pros and cons. It is well known that biodiesel is non-toxic, contains no aromatics, has higher biodegradability than fossil diesel, is less pollutant to water and soil and does not contain sulphur [7, 8]. It owes safer handling in the neat form and shows reduced oral and dermal toxicity, mutagenic and carcinogenic compounds. It is the most suitable fuel in environmentally sensitive areas (national parks, lakes, rivers) or in confined areas where environmental conditions and worker protection must meet high standards (underground mines, quarries) [9–11]. The main advantage of the use of KOME (biodiesel) is independent availability of raw material used for its production, the addition of KOME in traditional marine diesel fuel [12], improves the emissions of PM [13] which comprise a serious disadvantage of the diesel engine, especially in polluted areas like the Mediterranean Sea. However the low temperature operability of KOME in absolute mode is still imperative. Ethanol is a good depressant of viscosity, flash point, pour point and cloud point. This paper focuses on optimising the blending percentage of KOME with ethanol to study its effect on engine performance and emissions.

BOOST TO PRESENT STUDY

Marine diesel engine manufacturers in the United States, Europe and Japan have all recognized the growing role of biodiesel as a viable fuel component, and in most cases, as a fully alternative fuel (100%) [14]. the first research was by

Novak and Kraus [15] dates from the early 1970s on biodegradability and toxicity of biodiesel in aquatic environments. Since then, profuse researches have been followed up. After studying the biodegradability of several kinds of biodiesel and their comparison with commercial diesel and their blends, Zhang ET. al. [16] concluded that biodiesel is easily biodegradable in aquatic environments and has a higher biodegradability than commercial diesel. Research performed by Cytoculture revealed that 37% of the vessels surveyed chose to use biodiesel for environmental reasons, 33% for mechanical reasons (normally related to better lubricating properties of biodiesel), while 33% based their decision on subjective reasons, such as safety upon direct contact with the skin and lower smoke level. Von Wedel [14] also studied biodiesel toxicity in humans. In the aforesaid context the present study drives the authors to find out the feasibility of KOME as an absolute fuel in marine engines. However the imperative low temperature operability is the primacy of present research work.

CHEMISTRY OF PREPARATION (KOME)

Removal of Gums and Alkaloids

The crude Kusum oil was centrifuged at 9500 rpm in a REMI Model-24 centrifuge machine and the supernatant oil was collected free from heavy contaminates, 25 ml methanolic H_3PO_4 solution (12% v/v) was homogenized with 100 ml crude oil and allowed to stand for overnight. Next day, the oil was separated from methanol layer and precipitated compounds are filtered through silica gel (60–120 mesh) under suction. The filtrate, consisted of methanol and phosphoric acid, could be recycled three times for degumming Kusum oil. This makes the process economically more viable. After degumming, oil was kept overnight with 0.1% aqueous sodium hydroxide solution. Next day, aqueous portion was discarded and oil was washed twice with water to remove residual alkali. Then oil was heated on boiling water for 1 hour and then passed through warmed (warmed at 105 ^{0}C in an oven before use) anhydrous Na_2SO_3 to remove moisture from oil. Resultant oil was stored as refined alkaloid-free Kusum oil (RKO). After the whole process, 98% of the crude kusum oil(CKO) was converted to RKO.

Two Step Esterification

For esterification, degummed and alkaloid free oil (RKO) was mixed with sulphuric acid and methanol in the proportion of 50:10:1 (oil : CH_3OH : H_2SO_4, v/v/v) and stirred in a magnetic stirrer (5 lit capacity) at 900 rpm at 65 ^{0}C for 3 hours. After completion of esterification process, two layers were separated within 30 min. The lower layer was discarded and followed by neutralization with methanolic caustic soda solution and methanol was recovered from oil. The neutral oil was then mixed with sodium hydroxide and methanol in a ratio of 50:10:0.2 (oil : methanol : alkali) and stirred well mechanically at 900 rpm for 4 hours at 55 ^{0}C. After transesterification, oil was separated from lower layer by separating funnel and washed with hot water three to five times to remove impurities, and resultant transesterified oil (TEO) was stored for further analysis. After two-step transesterification, 92% of the RKO was converted to TEO.

PROPERTIES PRONE TO COMBUSTION (KOME)

SN and IV of oils were either noted from the literature or calculated from reported fatty acid methyl ester compositions of oil with the help of Eqs (1) and (2), respectively [17].

$$SN = \sum \left(560 \times A_i\right) / MW_i \qquad \textbf{(1)}$$

$$IV = \sum \left(254 \times D \times A_i\right) / MW_i \quad (2)$$

where, A_i is the percentage concentration of fatty acid components present in KOMEs of oil, D is the number of double bonds and MW_i is the molecular mass of each component.CN of FAMEs was calculated from Eq. (3) [18].

$$CN = 46.3 + \frac{5458}{SN} - \left(0.225 \times IV\right) \quad (3)$$

Table 1

Properties	Diesel	Kusum oil	KOME	KOME E20	KOME E10D10	ASTM D6751-02	DIN EN14214
Density	840	860	850-830	845-840	848-842	875-900	860-900
Calorific value(Mj/Kg)	43	35	38.863	38.91	38.83	40 min	49 max
Cetane number	45	40	42-48	43-48	43-48	----	-----
Kinematic Viscocity @ 40^0 C (Cst)	2.44	40.36	6	3.5	3.7	1.9-6	3.5-5.0
Flash point (^{0}C)	70	225	196	94	102	>130	>120
Fire point (^{0}C)	76	230	200	98	107	------	------
Cloud point (^{0}C)	-10 to -15	26	18	8	8.9	Summer=4 Winter= -1	Summer=6 Winter=1
Pour point (^{0}C)	-35 to -15	20	14	-4	-3	-----	-------
Saponification number	-----	190	130	120	122	-------	------
Iodine value	-----	64	57.9	55.3	55.8	------	--------

The table 1 shows most of the properties of KOME are comparable to petroleum based diesel fuel; improvement of its cold flow characteristic still remains one of the major challenges while using KOME as an absolute fuel for marine diesel engines. In present work, Ethanol is chosen as a cold flow improver since it has a very low solidifying temperature of the order of □114 ^{0}C and is highly soluble in KOME. Properties of ethanol like density and viscosity match well with that of KOME. Effects of ethanol–diesel blended biodiesel (KOME, KOME E10, KOME E20, and KOME E10 D10) were studied for engine performance evaluation and emission. KOME E20 shows better cold flow properties in low temperature region as depicted in Figure. 2.

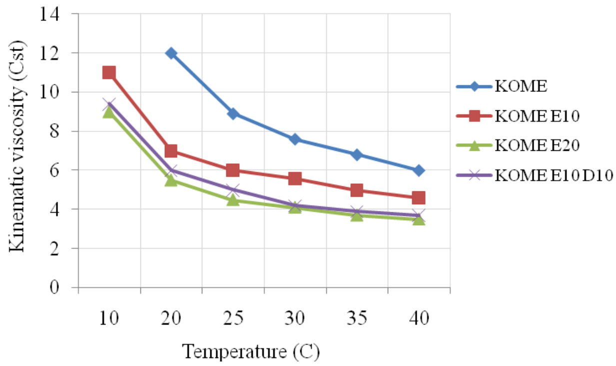

Figure 2: Variation of Kinematic Viscosity of Ethanol Blended KOME in Low Temperature Region

The low temperature operability of KOME and its blends with ethanol and ethanol-diesel blend were carried out following the ASTM standards D-2500, D-97 procedures, respectively. Four concentrations of ethanol and KOME blends, i.e. 5%, 10%, 15% and 20%, and KOME E10 D10 were tested for cold flow studies. The graph in figure.3 depicted better cold flow properties of KOME E20 in low temperature region.

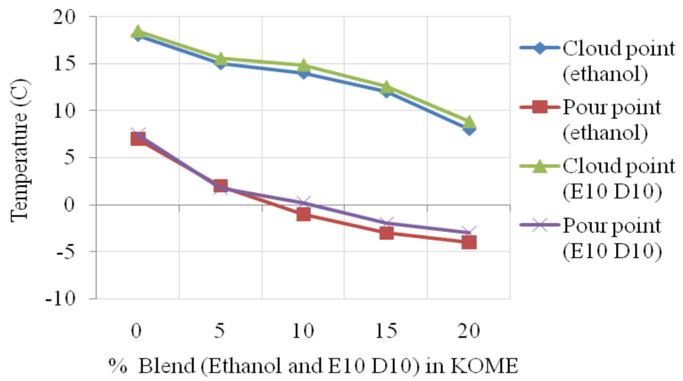

Figure 3: Effect of Ethanol and Diesel on Cold Flow Properties of KOME

ENGINE SETUP

A four stroke, water cooled and single cylinder engine coupled with edicurrent dynamometer was used for present study as shown in Figure. 4. The engine was computerised with engine soft (software) to measure the engine performance parameters. AVL gas analyser was employed to note the exhaust emissions such as carbon dioxide, hydrocarbon, carbon monoxide, oxygen, and nitrous oxides. Performance and emission parameters were noted for KOME, KOME E10, KOME E20, KOME E10 D10 and petroleum diesel. The reference study was based on petrolium diesel to interpret the data for comparison. The test was conducted at 1500 rpm with varing loads. Table 2 shows the engine specifications.

Table 2: Engine Specification

Engine	Kirloskar TV1
General details	4 stroke CI water cooled single cylinder computerised
Bore x Stroke	87.5 mm x 110 mm
Compression ratio	17.5 : 1 (varing from 16:1 to 18:1)
Displacement	661 cc
Power	3.5 kW
RPM	1500

Figure 4: Variable Compression Ratio Test Rig

ENGINE PERFORMANCE ANALYSIS

Brake Power

Figure 5 depicts brake power of KOMEE20 stands high subsequent to petroleum diesel with increasing load on the engine. KOME shows inferior values subsequent to KOMEE20, KOMEE10D10 and KOME10 due to high viscosity, flash or fire point and low calorific value, than that of commercial diesel with a power loss close to 5%. However KOMEE20 shows a power loss of 2% with improved low temperature operability, comparable viscosity, calorific value and flashpoint to commercial diesel. Research says biodiesel is easily biodegradable in aquatic environments and has a higher biodegradability than commercial diesel [16]. So ethanol blend up to 20% can be recommended for marine diesel engines without any modification or adulteration.

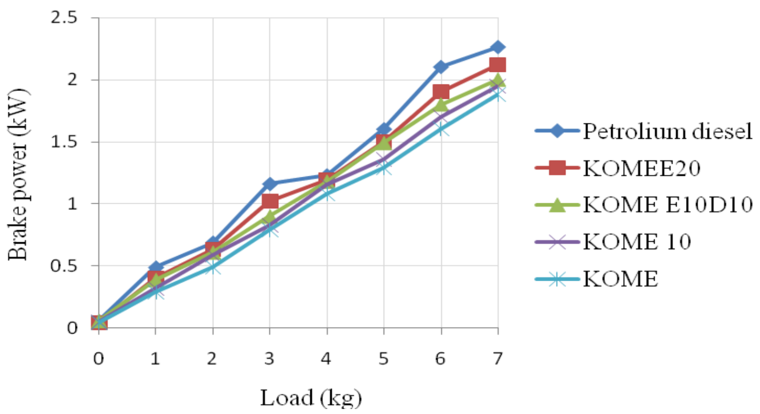

Figure 5: Variation of Brake Power with Load

Brake Mean Effective Pressure

Figure 6 reveals the BMEP of KOME budges below subsequent to commercial diesel, KOMEE20, KOMEE10D10 and KOME10 with increasing load on the engine. This is attributed to high viscosity, flash point and low calorific value. A pressure loss nearly equal to 4% is obtained at the highest load of 7 kg performed by the engine. However KOMEE20 shows a pressure loss of 1% at the same load with improved cold flow properties, comparable viscosity, flash point and calorific value to commercial diesel. Favourably research says biodiesel is easily biodegradable in aquatic environments and has a higher biodegradability than commercial diesel [16]. So ethanol blend up to 20% can be recommended for marine diesel engines without modification or adulteration.

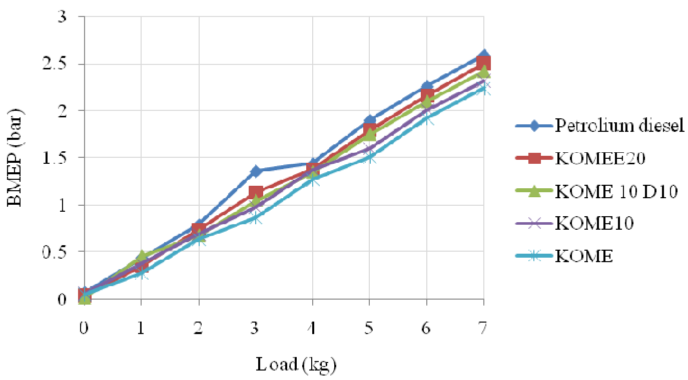

Figure 6: Variation of BMEP with Load

Brake Thermal Efficiency

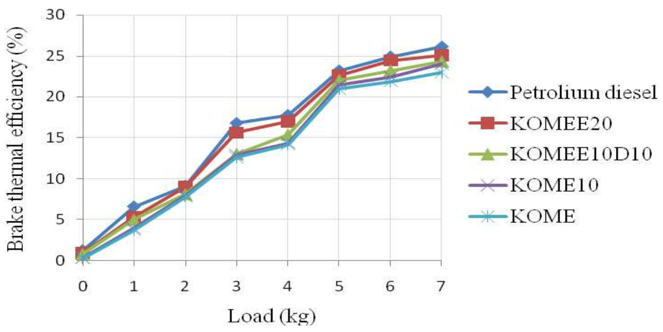

Figure 7: Variation of Brake Thermal Efficiency with Load

Figure 7 depicts KOMEE20 push over the thermal efficiencies of KOMEE10D10, KOMEE10 and KOME subsequent to commercial diesel with increase in load on the engine. KOMEE20 shows a thermal efficiency loss near to 2%. This may be attributed to a blend concentration of ethanol up to 20% which is a low cost depressant of poor cold flow properties, viscosity, and flash or fire point. Moreover research says biodiesel is easily biodegradable in aquatic environments and has a higher biodegradability than commercial diesel [16].Hence KOMEE20 can be recommended as an absolute fuel for marine diesel engines without any modification or adulteration.

Specific Fuel Consumption

With increase in load, the fuel consumption per unit power generation decreases which is a desired engine performance. Figure8 depicts KOMEE20 push over KOMEE10D10, KOMEE10 and KOME subsequent to commercial diesel which may be attributed to a blend concentration of ethanol up to 20%, a low cost depressant of poor cold flow properties, viscosity and flash or fire point. Moreover research says biodiesel is easily biodegradable in aquatic environments and has a higher biodegradability than commercial diesel [16]. Hence KOMEE20 can be recommended as an absolute fuel for marine diesel engines without any modification or adulteration.

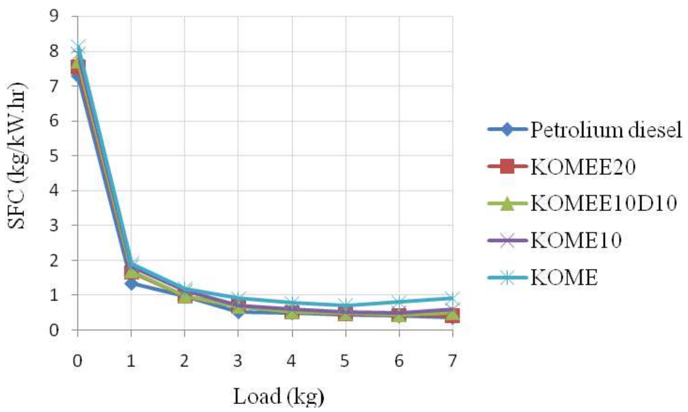

Figure 8: Variation of Brake Thermal Efficiency with Load

ENGINE EMISSION ANALYSIS

Emission Analysis of KOMEE20

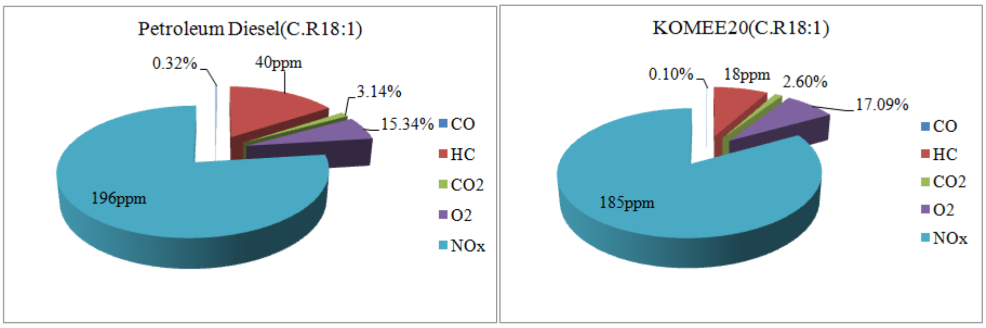

Figure 9: Emission Comparison between Petroleum Diesel and KOMEE20

Figure 9 depicts the emission comparison between petroleum diesel and KOMEE20. The combustion of KOMEE20 exhibits emissions of CO and CO_2, less in comparison to petroleum diesel. Hazardous unburnt hydrocarbon and nitrous oxide is also less than that of petroleum diesel. Free oxygen release is 2% more than that of petroleum diesel which indicates a proximal combustion to petroleum diesel with fewer emissions nevertheless negligible power loss. However research says the hazardous emissions are more biodegradable in aquatic environments than petroleum diesel [16]. Hence KOMEE20 can be recommended as an environmental friendly absolute fuel in marine diesel engines without any modification or adulteration.

Emission Analysis of KOMEE10D10

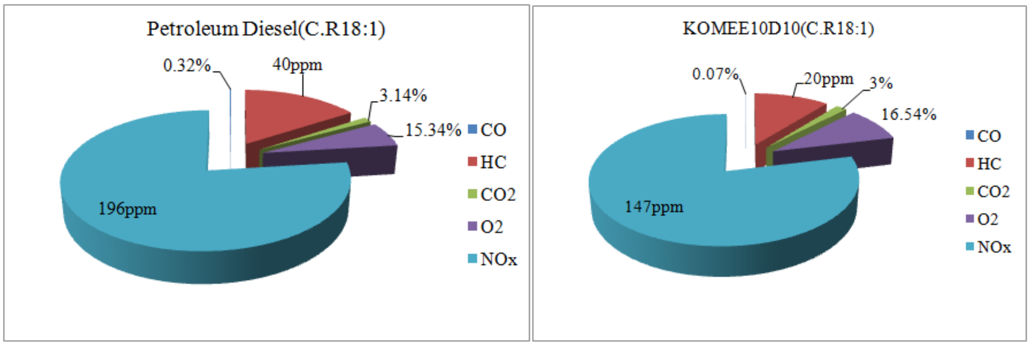

Figure 10: Emission Comparison between Petroleum Diesel and KOMEE10D10

Figure 10 depicts the emission comparison between petroleum diesel and KOMEE10D10. Combustion of COMEE10D10 reveals emissions of CO and CO_2, less in comparison to petroleum diesel. Hazardous unburnt hydrocarbon and nitrous oxide is also less than that of petroleum diesel. Free oxygen release is 2% more than that of petroleum diesel indicates a proximal combustion to petroleum diesel with fewer emissions nevertheless negligible power loss. However KOMEE10D10 owes poorer cold flow properties, higher viscosity, and higher flash point than that of petroleum diesel and KOMEE20 attributing a combustion durability problem, clogging of fuel filter in long run. Preheating up to 60 ^{0}C may mitigate the problem. Hence KOMEE10D10 is the best absolute fuel next to petroleum diesel and KOMEE20 in marine diesel engines without any modification or adulteration as hazardous emissions are more biodegradable in aquatic environments than petroleum diesel [16].

Emission Analysis of KOMEE10

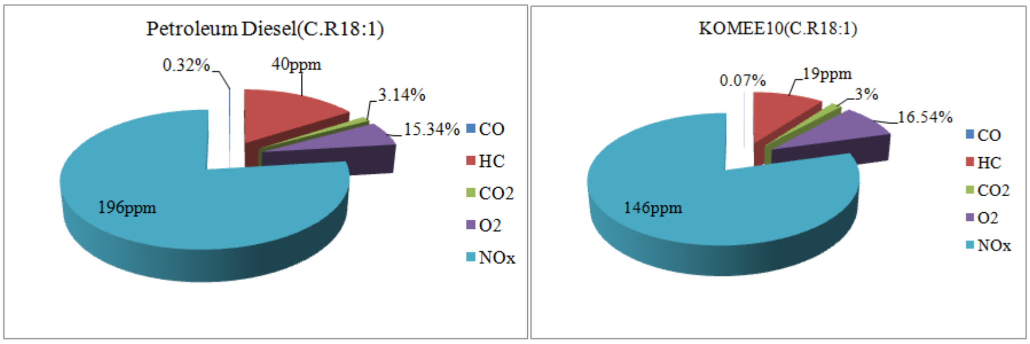

Figure 11: Emission Comparison between Petroleum Diesel and KOMEE10

Figure 11 depicts the emission comparison between petroleum diesel and KOMEE10. Combustion of KOMEE10 reveals emissions of CO and CO_2, less than that of petroleum diesel. Hazardous unburnt hydrocarbon and nitrous oxide is also less than that of petroleum diesel. Free oxygen release is nearly 2% more than that of petroleum diesel indicates a proximal combustion to petroleum diesel with fewer emissions. However KOMEE10 owes poorer cold flow properties, higher viscosity, and flash point than that of petroleum diesel, KOMEE20, KOMEE10D10 attributing to a combustion durability problem, clogging of fuel filter in long run. Preheating up to 100 ^{0}C may mitigate the problem. Hence KOMEE10 is the best absolute fuel next to petroleum diesel, KOMEE20, KOMEE10D10 in marine diesel engines with a little modification in engine hardware facilitating preheating up to 100 ^{0}C.

Emission Analysis of KOME

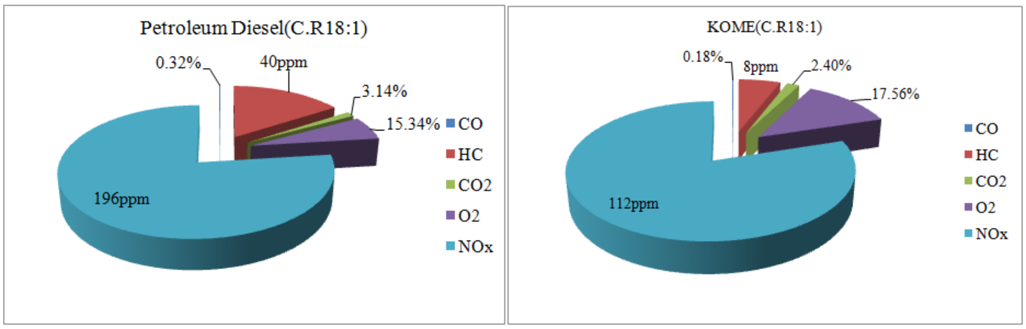

Figure 12: Emission Comparison between Petroleum Diesel and KOME

Figure 12 depicts the emission comparison between petroleum diesel and KOME. Combustion of KOME reveals emissions of CO and CO_2, less than that of petroleum diesel. Hazardous unburnt hydrocarbon and nitrous oxide is also less than that of petroleum diesel. Free oxygen release is nearly 2% more than that of petroleum diesel indicates a proximal combustion to petroleum diesel with fewer emissions. However KOME owes poorer cold flow properties, higher viscosity, and flash point than that of petroleum diesel, KOMEE20, KOMEE10D10 and KOMEE10, attribute to a combustion durability problem, clogging of fuel filter in long run. Preheating up to 100 ^{0}C may mitigate the problem. Hence KOME is the best absolute fuel next to petroleum diesel, KOMEE20, KOMEE10D10 in marine diesel engines with a little modification in engine hardware facilitating preheating up to 100 ^{0}C.

CONCLUSIONS

This study experimentally analyzed the remission of poor cold flow performances, viscosity, flash and fire points by blending with ethanol and petroleum diesel. Ethanol up to 20% concentration in KOME proved to be the best depressant of combustion problems. Engine performances and exhaust emissions of KOME, KOMEE10, KOMEE10D10 and KOMEE20 and petroleum diesel inferred KOMEE20 to be the best absolute fuel next to petroleum diesel in marine diesel engines, compensating 80% of total diesel combustion. Hazardous emissions are more biodegradable in aquatic environment. So KOMEE20 can be recommended for marine diesel engines without any engine modification or adulteration.

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