Experimental Investigation On Performance And Emission Characteristics Of A Diesel Engine Fuelled With Karanja Oil Methyl Ester Using Additive

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***Abstract*— In the present work Karanja oil is used as a source for biodiesel production via base catalyzed transesterification and biodiesel produced in the process is mixed with an additive (Dimethyl Carbonate) in varying volume proportions to prepare a number of test fuels for engine application. Experiments were carried out on a four stroke single cylinder constant speed direct injection diesel engine under varying load condition to investigate about the performance and emission characteristics of the engine fuelled with the present test fuels. The results of investigation show increase in brake power and brake thermal efficiency with load for all test fuels. It is also noticed that the brake thermal efficiency increases with the percentage of additive in the test fuels. The brake specific fuel consumption decreases with increase in additive percentage in the test fuels. The exhaust gas temperature increases almost linearly with load for all test fuels and decreases with increase in additive percentage in the fuel. Results show that the CO and HC emissions tend to decrease with increase in additive percentage in biodiesel. The smoke and NOx emissions also decrease with increase in additive percentage in the biodiesel fuel.**

Keywords—Karanja oil, Biodiesel, Additive, Performance, Emission

I. INTRODUCTION

Due to excess use of the petroleum based fuels for industry and automobile application in present time, the world is facing severe problems like global energy crisis, environmental pollution and global warming. Therefore global consciousness has started to grow to prevent the fuel crisis by developing alternative fuel sources for engine application. Many research programs are going on to replace diesel fuel with a suitable alternative fuel like biodiesel. Non-edible sources like Mahua oil, Karanja oil, Neem oil, Jatropha oil, Simarouba oil etc. are being investigated for biodiesel production. Fatty acids like stearic, palmitic, oleic, linoleic and linolenic acid are commonly found in non-edible oils [1]. Vegetable oils blended with diesel in various proportions has been experimentally tested by a number of researchers in several countries. In developing countries like India, it is easily possible to grow these non-edible vegetable oils but not economically feasible to convert them to methyl esters undergoing different types of chemical process [2], [3]. Therefore, preheated oils blended with diesel are used and tested as alternative fuels in engines. This paper describes the findings of experiments conducted on a diesel engine to investigate about its performance and emission parameters with a number of test fuels prepared from Karanja biodiesel and an additive (Dimethyl carbonate). The purpose of using an additive in blended form with biodiesel is to enhance the combustion and lower the engine exhaust emissions.

A. Transesterification reaction

Transesterification is a reversible reaction between triglyceride and alcohol in presence of catalyst to produce glycerol and mono alkyl ester which is known as biodiesel [2]-[4]. Weight of the mono alkyl ester is one third of that of typical oil and therefore has lower viscosity. Alkali (NaOH, KOH), acid (H2SO4, HCL) or enzymes (lipase) catalyzed reaction. Acid catalyzed transesterification is most commonly used process because it is a reversible reaction. In the transesterification process methanol and ethanol are more common. Methanol is more extensively used due to its low cost and physiochemical advantages with triglycerides and alkali are dissolved in it [5]. Studies have been carried out on different oils like Soyabean, Sunflower, Jathropa, Karanja, Neem, etc. Mostly biodiesel is produced by base catalyzed transesterification process of vegetable oil and it is more economical. Here the process is a reaction of triglyceride with alcohol to form mono alkyl ester commonly known as biodiesel and glycerol as by product. The main reason for doing titration to biodiesel is to find out the amount alkaline needed to completely neutralize any free fatty acid present, thus ensuring a complete transesterification [3], [4].

The chemical reaction which describes the preparation of biodiesel is:

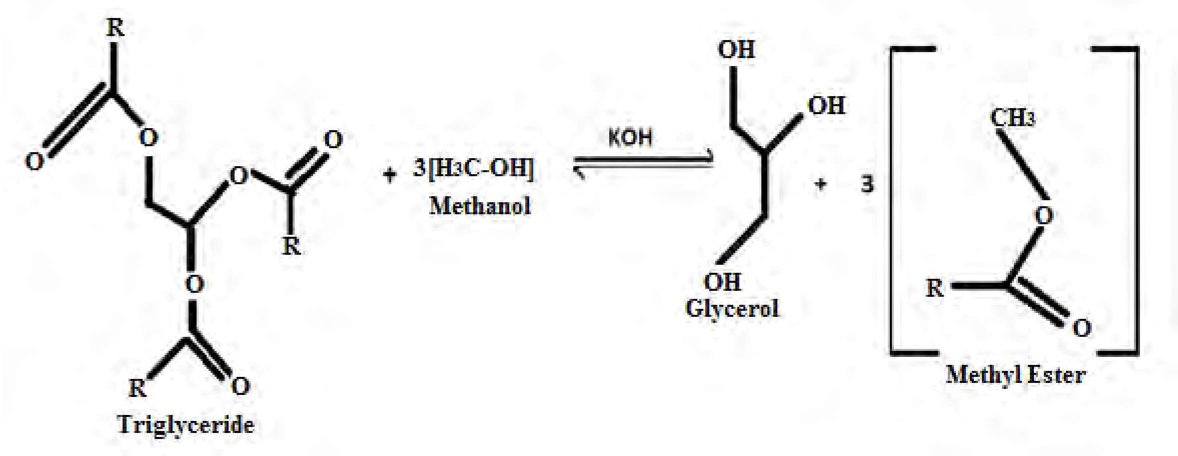

Fig. 1 Reaction process for transesterification.

II. Materials And Methods

A. Materials

1) Karanja (Pongamia Pinnate)

It is available in western ghats of India. The average life of Karanja tree is 80-100 years and grows to a height of 40 feet. It can grow in humid and subtropical environment within sustainable temperature of 5-50 0C and an average rainfall of 600-2500 mm. The average yield of kernel per tree is about 9-90 Kg per year and the oil production is approximately 1,35,000 metric tons per year in India [6]

TABLE I
Fatty acid composition in Karanja oil (Pongamia Pinnate).

Sl.No	Fatty acid	Structure	Weight (%)
1	Palmitic	C16:0	11.6
2	Stearic	C18:0	7.5
3	Arachidic	C20:0	1.7
4	Oleic	C18:1	51.5
5	Linoleic	C18:2	16.0
6	Linolenic	C18:3	2.6
7	Lignoceric	C24:0	1.0

2) Dimethyl carbonate

Di methyl carbonate is a colourless, transparent liquid under normal temperature. Some important properties of it are given in Table 2.

TABLE III
Properties of Dimethyl Carbonate.

Molecular Formula	$C_3H_6O_3$
Molar mass	90.08 gm/mole
Appearance	Clear liquid
Density	1.069-1.073 gm/mole
Melting point	(275-277 K)

B. Methodology

One litre of neat Karanja oil is heated in an open beaker to a temperature of 100-110 0C to remove water particles present in oil followed by filtration of oil. The oil is processed under base catalyzed transesterification method where it is mixed with 200 ml of methanol and 6.5 gms of sodium hydroxide pellets in a round bottom flask on a hot plate magnetic stirring arrangement for 1-1.5 hours upto 60 0C and then it is allowed to settle down for about 6-8 hours to obtain biodiesel and glycerol. The biodiesel obtained in the process is further washed with distilled water for 2 to 3 times for removal of acids and heated above 100oC to separate the moisture present in the biodiesel. Hence pure Mahua biodiesel is obtained.

C. Preparation of test fuel blends

Various test fuel blends were prepared by blending Karanja biodiesel with additive in various volume proportions. In the present work B85, B90, B95, B100 and the diesel fuel are used as the test fuels where B85 represent 85% biodiesel and 15% additive. Similarly B90 and B95 represents 90% biodiesel with 10% additive and 95% biodiesel with 5% additive respectively. B100 represents pure biodiesel without additive.

III. EXPERIMENTATION

A. The Test engine

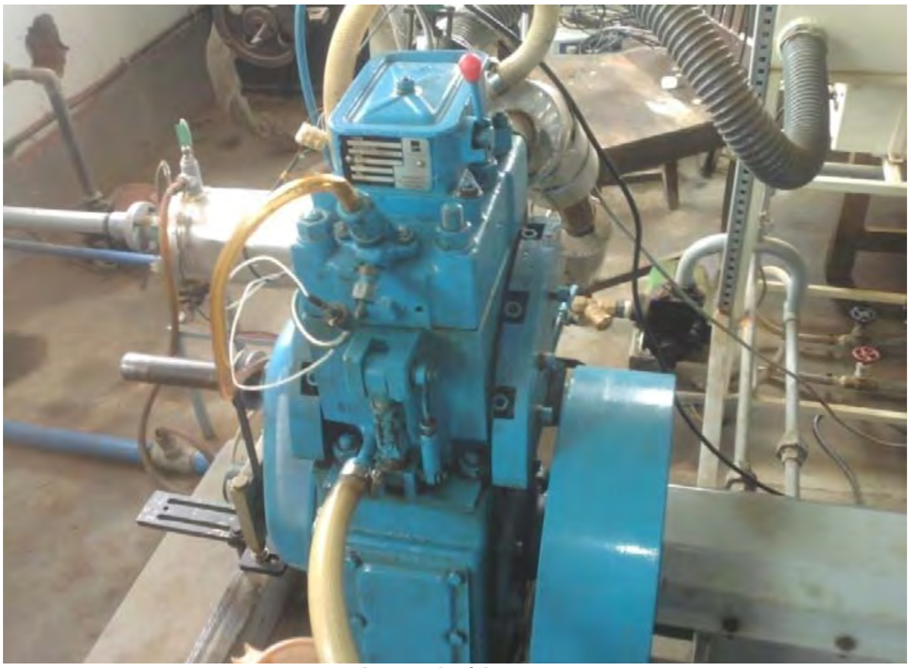

Fig. 2 Photograph of the test engine.

TABLE IIIII
Test Engine Specification.

Sl.No	Particulars	Description
1	Engine type	Single cylinder, 4-stroke. vertical water cooled diesel engine
2	Bore diameter	80 mm
3	Stroke length	110 mm
4	Compression ratio	16.5:1
5	Rated power	3.67 KW
6	Rated speed	1500 rpm
7	Dynamometer	Eddy Current type

The test bed consist of a four stroke single cylinder direct injection water cooled diesel engine equipped with eddy current dynamometer, orifice meter in conjunction with U-tube manometer measuring volume flow rate of air, graduate burette for volume flow rate of fuel in (cc) and measuring jar for measuring cooling water flow rate. The prepared bio-diesel is poured into the cylindrical tank. Then the level of fuel and lubricating oil is checked. The 3-way cock is opened so that the fuel flows to the engine. Cooling water is supplied through the inlet pipe. The engine is then started with the supply of the fuel. The speed of the engine is kept constant at 1500 rpm under varying load conditions and performance parameters like brake power, torque, brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature were measured for diesel and all test fuels. CO, HC, CO_2 and NOx emissions were also measured for both diesel and all test fuels with the help of a multi gas analyzer.

B. Characterization of test fuels

TABLE IV
Comparison of fuel properties for diesel and Mahua biodiesel

Sl.No	Properties of fuel	Unit	Diesel	Karanja biodiesel
1	Density	(Kg/m3)	834	918
2	Kinematic viscosity at 40 ^{0}C	cSt.	4.57	5.39
3	Specific gravity at 15 ^{0}C	-	0.8668	0.8712
4	Flash point	^{0}C	42	157
5	Fire point	^{0}C	68	183
6	Pour point	^{0}C	5	2
7	Cloud point	^{0}C	4	9
8	Cetane number	-	43	29.83
9	Calorific value	KJ/Kg-K	42850	42293
10	Carbon	(% W/W)	80.13	74.61
11	Hydrogen	(% W/W)	11.96	9.98
12	Nitrogen	(% W/W)	1.576	0.0
13	Oxygen	(% W/W)	1.09	12.46
14	Sulphur	(% W/W)	0.35	0.0

IV. RESULTS AND DISCUSSION

A. Brake thermal efficiency (BTE)

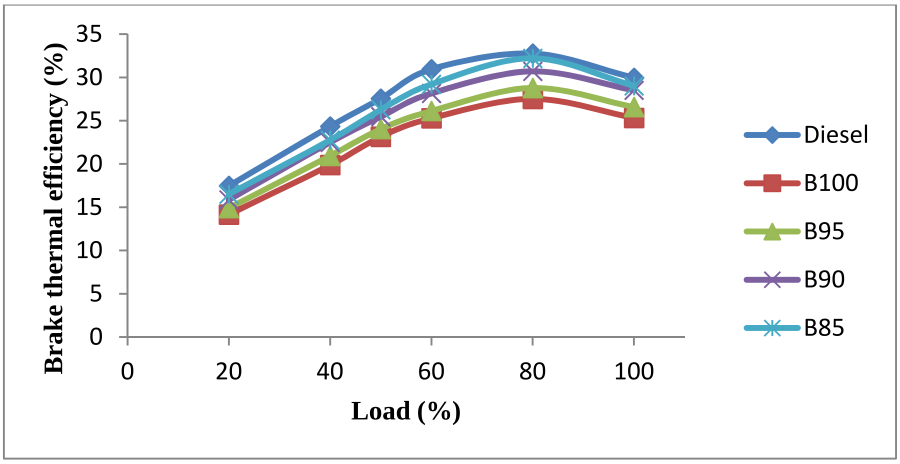

Fig. 3 Variation in brake thermal efficiency with load

Fig. 3 shows that the brake thermal efficiency for all test fuels increase with load and is higher for test fuels having more additive percentage. BTE is found lower for pure biodiesel due to its higher viscosity and lower calorific value [6], [7].

B. Brake specific fuel consumption (BSFC)

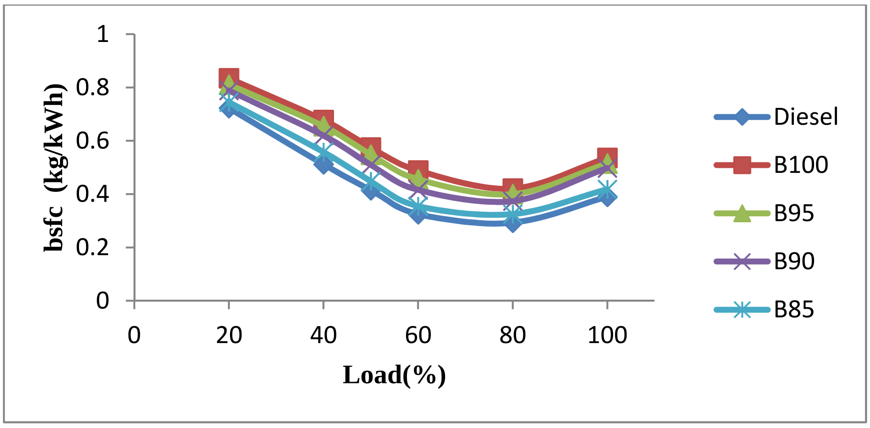

Fig. 4 Variation in brake specific fuel consumption with load.

From Fig. 4 it is observed that diesel has lower bsfc where as pure biodiesel exhibits highest bsfc at all loads which is due to higher density and viscosity and lower heating value of biodiesel [6], [7]. Results also show that bsfc reduces as the percentage of additive increases in the fuel. This may be due to better combustion with increased additive percentage.

C. Exhaust gas temperature (EGT)

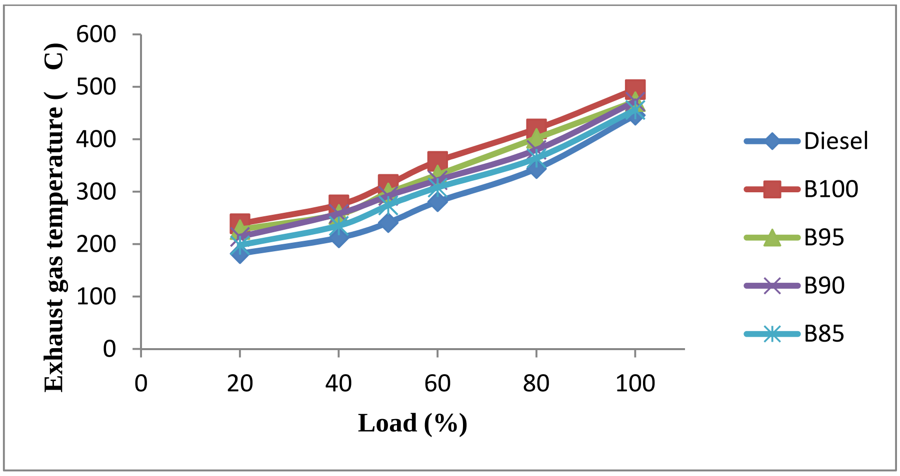

Fig. 5 Variation in exhaust gas temperature with load.

From Fig. 5 it is observed that the exhaust gas temperature increases almost linearly with load for all test fuels. Diesel exhibits lower exhaust temperature when compared with all other test fuels. Biodiesel exhibits highest exhaust temperature at all loads which is due to higher combustion temperature of biodiesel because of higher oxygen content [7], [8]. Results also show slight decrease in EGT with increase in additive percentage in biodiesel. From the above figure it is concluded that B85 shows lowest exhaust temperature compared to all other additive blends because of high oxygen content than that of diesel.

D. CO emission

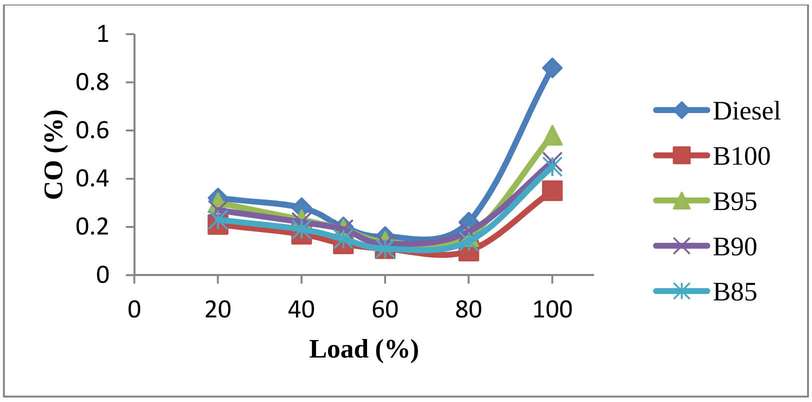

Fig. 6 Variation in CO emission with load.

The CO emission depends solely depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. From Fig. 6 it is observed that the CO emission initially decreases at lower loads sharply increases after 80% load for all test fuels. This is due to incomplete combustion at very high loads which results in higher CO emissions [8]. CO emission is found highest for diesel and lowest for pure biodiesel at all loads. It is also seen that the CO emission decreases with increase in percentage of additive in the blends. From the figure it is revealed that B100 shows lowest carbon monoxide emission compared to all other test fuels upto 80% load and then increases due to incomplete combustion.

E. HC emission

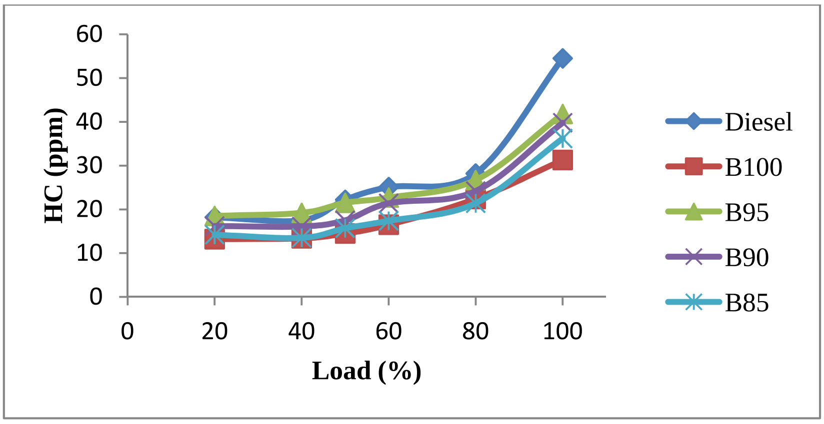

Fig. 7 Variation in HC emission with load

The HC emission solely depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. Fig. 7 shows that the HC emission increases with load for all test fuels. Also the increase in HC emission is sharp above 80% load. This is again due to incomplete combustion at very high loads which causes higher HC emission [8], [9]. It is also seen that the HC emission decreases with increase in additive percentage in biodiesel. B85 shows lowest HC emission at 80% load and then increases due to incomplete combustion.

F. Smoke emission

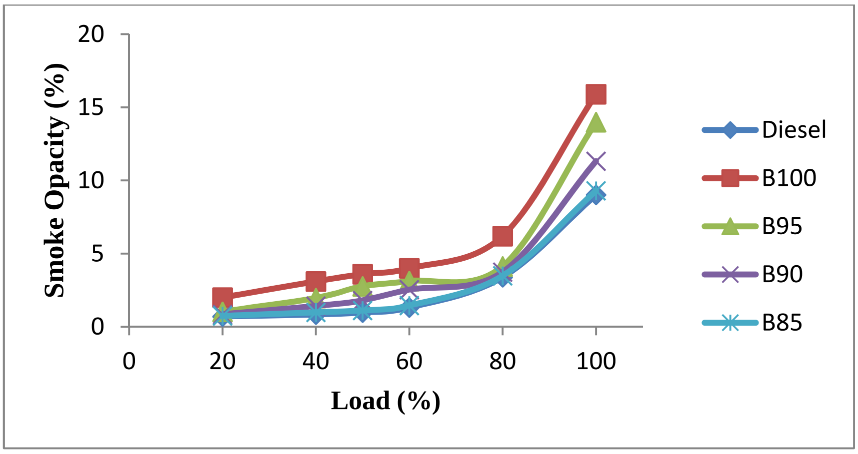

Fig. 8 Variation in smoke emission with load

From Fig. 8 it is observed that the smoke emission for all test fuels almost linearly increases upto 80% load and then increases very sharply which is due to incomplete combustion and lack of oxygen at very high loads [9]. Highest smoke emission is observed for pure biodiesel and lowest for diesel which is because of lower heating value and higher viscosity of biodiesel [9], [10]. It is also seen that smoke emission decreases with increase in additive percentage in the biodiesel. B85 shows lowest smoke emission compared to other test fuels upto 80% load and then increases due to incomplete combustion and deficiency in oxygen at higher loads.

G. *NO_x emission*

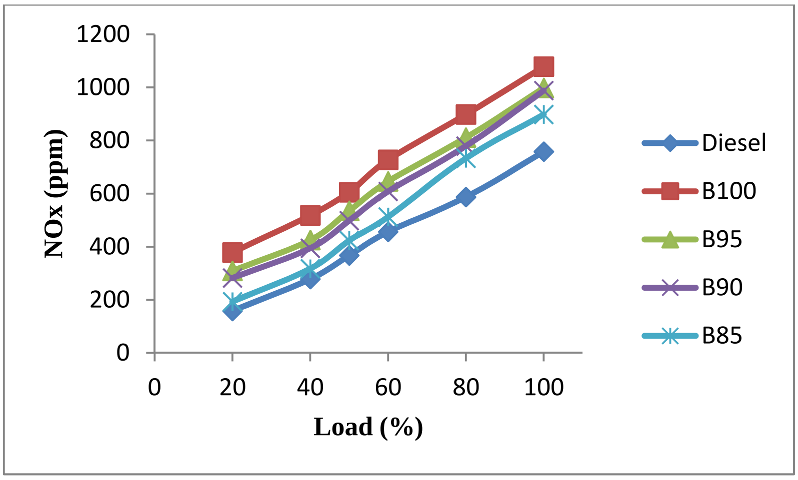

Fig. 9 Variation in NOx emission with load

The NOx emission depends solely depends upon the oxidation of nitrogen at high temperature. The results obtained in Fig. 9 show that NOx emission increases with engine load for all test fuels. It is found highest for pure biodiesel and lowest for diesel at all loads. Higher NOx emission in case of biodiesel is due to the fact that it contains higher oxygen which results in higher combustion temperature [9], [10]. Results also show decrease in NOx emission with higher additive percentage in biodiesel. From the figure it is revealed that B85 shows lower nitrogen oxide emission compared to other additive blends.

CONCLUSION

From the present experimental investigation the following conclusions are drawn.

- The brake thermal efficiency increases with increase in additive percentage in biodiesel and it is lower in case of pure biodiesel.
- Brake specific fuel consumption is highest for pure biodiesel and decreases with increase in additive percentage in biodiesel.
- Exhaust gas temperature is found highest for pure biodiesel and tends to decrease with increase in additive percentage in biodiesel.
- CO and HC emission are found highest for diesel and decrease with increase in additive percentage in biodiesel.
- Smoke and NOx emissions are found highest for pure biodiesel and decrease with increase in additive percentage in biodiesel.

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