Almond, Undi, and Sesame Oils as Biodiesel Feedstocks: A Comparative Analysis

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ABSTRACT
Global warming and environment pollution become a serious problem for today world. As we all know that in today scenario, energy demand is rapidly increases due to the growth of production. In today market, fossil fuel is the main source of energy so its demand is very high. Fossil fuel is the main cause of environment pollution and for global warming. Environment pollution has a negative impact on human health. So we need good fuel so that we reduced the environment pollution. Biodiesel is a new source to fulfill increased energy demand and also control the environment pollution. The quality of exhaust gas emission is better for biodiesel fuel compare to diesel fuel. During the last two decade (1984-2004) primary energy has grown by 49% and CO2 emission by 43%, with an average annual increase of 2% and 1.8% respectively. My study is based on Biodiesel production from almond oil, undi oil and sesame oil. Produced biodiesel used as a fuel in diesel engine and checked its impact on engine performance, engine emission and the environment.

INTRODUCTION
The increasing industrialization, modernization and development have led to high demand of petroleum worldwide. Fossil fuel is the main source of petroleum. But due to depleting of fossil fuel and its higher cost triggered to find new alternative fuel source. Nowadays biodiesel is new found fuel that can be used in place of petroleum fuel. Biodiesel is mainly prepared by vegetable oil or animal fats oil. There are several methods to convert vegetable oil or animal fats oil into biodiesel, wherein transesterification method is the most used common technique that includes a lipid reaction with alcohol and gets glycerol and fatty acid alkyl esters. The reaction can be categorized into a non-catalytic and catalytic method in which either homogeneous or heterogeneous catalysis reaction occur. Generally, homogeneous catalysts are preferred and amongst these, an alkaline catalyst such as sodium hydroxide have been used as a most effective type. In alcohol, methanol is generally preferred due to its physical property and low cost compare to ethanol. There are many factors that affect the transesterification reaction like as alcohol type, molar ratio (alcohol to oil), catalyst concentration, reaction time, reaction temperature, mixing rate and properties of the feedstock. Straight Vegetable Oil (SVO) can be directly used in the engine but it possesses serious problem due to high viscosity. So the reduction in viscosity can be accomplished by transesterification technique. Biodiesel fuel has similar properties to diesel fuel. Biodiesel seems to be an accurate substitute of diesel fuel and realistic renewable fuel in the near future. This paper is focused on the possibilities of using almond oil, undi oil and sesame oil by comparing the properties of the diesel fuel with these oils and their biodiesel. Emission analysis of different biodiesel is also discussed.

Production of biodiesel
There are many standardized procedures for the production of biodiesel [3]. The commonly used methods for preparation of biodiesel described on below

Blending
In this method, vegetable oil is mixed with diesel in a certain proportion. The disadvantages of vegetable oils as diesel fuel are high viscosity, lower volatility and the reactivity of unsaturated hydrocarbon chain. Problems appear only after the engine has been operating on vegetable oils for longer periods of time, especially with direct-injection engines.

Transesterification
Transesterification (also called alcoholysis) is a chemical reaction of animal fat or vegetable oil with an alcohol in the presence of a catalyst to form esters (biodiesel) and glycerol. Catalyst increases the reaction rate and production yield. Alcohol converts the triglycerides into ester.

$CH2-OOC-R1$			$R1-COO-R$		$CH2-OH$
I			I		I
$CH2-OOC-R2$	+ 3ROH	KOH ⟷	$R2-COO-R$	+	$CH2-OH$
I			I		I
$CH2-OOC-R3$			$R1-COO-R$		$CH2-OH$
Triglycerides	Alcohol	Catalyst	Methyl Ester		Glycerol

The alcohols which are mainly used in transesterification process are ethanol and methanol butanol propanol and amyl alcohol but among these methanol and ethanol is generally used especially methanol. The reaction is catalyzed by any one of the acidic, alkalis or enzyme catalyst. In alkali catalysts, KOH and NAOH are mostly used.

Thermal cracking (Pyrolysis)

In the thermal cracking process, Vegetable oil or animal fatty oil is heated in the absence of air or oxygen in the temperature superior to 450 ºC and break the molecules by heating. After heating, we get a mixture of chemical compounds with similar properties like petrodiesel.

Micro-emulsification

Microemulsion involves mixing of oils with suitable emulsifying agents such as alcohol mainly methanol, ethanol, propanol or butanol to form emulsions. The main demerit associated with the use of micro emulsion engine fuel is the formation of deposits of carbon in the engine and incomplete combustion [4].

CHARACTERIZATION OF OILS

Effect of methanol to oil molar ratio

The stoichiometry of transesterification reaction required three mol of alcohol for one mol of triglyceride. Transesterification is an equilibrium reaction. A large excess of alcohol is necessary to drive the reaction to the right. A molar ratio of 6:1 is normally used to get higher yield of ester (greater than 98% by weight). Initially when increasing methanol to oil molar ratio, the percentage yield of biodiesel increases up to the highest limit. The percentage increment in biodiesel yield gradually decreased with increase in the molar ratio.

Effect of catalyst type and concentration

Another important variable affecting the yield of ester is the catalyst type and concentration. There is various type of catalysts like as alkali, acid, enzyme or heterogeneous catalysts. In which, alkali catalyst is more effective like NaOH, KOH, NaOMe, KOM etc. Standard catalyst concentration lies between 0.5% and 1.7%. Initially increasing the catalyst concentration biodiesel yield increased up to the highest peak after that it will start to decrease due to…….

Effect of reaction time and temperature

The rate of reaction is strongly affected by the temperature Yield of biodiesel depend on the reaction temperature. While increasing the temp it has been found to speed up the reaction and get more yield. This happens due to the reduction of oil viscosity while increasing the temperature resulting in better mixing of alcohol with oil and faster separation process of glycerol from biodiesel. However, given sufficient time, the reaction will proceed to near completion even at room temperature. The uppermost yield of esters found at temperatures ranging from 60 ºC to 80 ºC at a molar ratio of (alcohol to oil) 6:1. Further increasing temperature, the yield of esters have a negative effect on the conversion

PROPERTIES OF VEGETABLE OIL AND THEIR BIODIESEL

The properties of almond oil, undi oil and sesame oil, which have the potential for replacement of diesel oil and their esters are given in Table 1 and Table 2.

Table 1. Properties of almond oil sesame oil and undi oil [14, 12]

	Percentage fatty acid	
	saturated	unsaturated
almond oil	8.4	90.7
sesame oil	18	78
undi oil	31	68.1

Table 2. Properties of Almond oil, undi oil and sesame oil compared with diesel [1, 6, and 15]

S no	properties	Diesel	Almond oil	undi oil	Sesame oil
1	Specific gravity[at 25 ºC]	0.848	0.911	910	0.913
2	Kinetic Viscosity [at 40 ºC cSt]	3.384	24.72	32.48	35.5
3	Calorific value (MJ/kg)	48.61	41.761	39.100	39.349
4	Flash point °C	68	213	224	260
5	Cetane no	43	54.32	NA	40.2

NA=NOT AVAILABLE

Almond and sesame oil come in edible oil category whereas undi oil comes in the non-edible category. An economical point of view, we should use non-edible oil. The properties of almond and undi and sesame oil compare with diesel fuel and found that kinetic viscosity sesame oil is 32.48cSt that is very high compared to diesel 3.384cSt. Similarly, undi oil has 32.48cSt and almond oil has 24.72cSt. We can use it in the engine but its high viscosity damages the engine in short period of time.

Table 3. Fuel properties of AOME, UOME and SOME compared with diesel [1, 2, 5, 18]

Name of fuel property	Diesel	AOME	UOME	SOME	ASTM D6751	EN14214
Density (gm/cc^3)	0.83	0.911	869	0.8712	-	0.860-0.90
Viscosity (cSt)	3.7	4.726	4	5.77	1.9-6.0	3.5-5.0
Flash point (ºC)	60	145	140	110	>130	>101
Fire point (ºC)	65	154			-	Min 120
Cloud point (ºC)	-12		13.2	-6.3	10	-1
Pour point (ºC)	-16		4.3	18	-15	-
Calorific value (MJ/kg)	43	41.761	41.397	40.4	-	-
Cetane NO	47.48	49.23	57	50.48	-	-

Flash point of almond oil is higher compared to undi and sesame oil.so almond oil is more secure safety point of view. Its viscosity also satisfies the ASTM D6751 and EN14214 norms. The calorific value of almond oil is also higher compared to undi and sesame.

INFERENCES MADE BY RESEARCHERS

There are many researchers who have been working in biodiesel production and its engine testing. Few of them with their work detail given below

Atapour and Kariminia 2010 [7] investigated the production of biodiesel using the bitter almond oil by adopting the transesterification reaction process. Potassium hydroxide (KOH) was used as a catalyst. The content of unsaturated fatty acids in a BAO is high that is confirmed by fatty acid content analysis. Effect of different parameters including reaction temperature (30-70 ºC), catalyst concentration (0.1-1.7% w/w) and methanol to oil molar ratio (3-11 mol/mol) on product yield, biodiesel purity and biodiesel yield was investigated. The effect of temperature is little on product yield while temperature varies from 30-50 ºC. However, with increasing the temperature from 50-70 ºC the product yield decreased. Biodiesel purity and yield was increased with temperature varies from 30-50 ºC. The maximum value of Biodiesel purity and yield was obtained at 50 ºC. Further, increase the temperature value from 50-70 ºC then biodiesel purity and yield was starting to decreased. While KOH catalyst concentration varies from 0.1 to 0.9% w/w the product yield was approximately constant but biodiesel purity and biodiesel yield increased. The maximum value of biodiesel yield (90.8% w/w) was obtained at 0.9% w/w catalyst concentration. Biodiesel yield, product yield and biodiesel purity were increased with increasing the value of methanol to oil molar ratio from 3:1 to 7:1. Further increase the molar ratio of methanol to oil, the little effect on product yield. However with increase the molar ratio of methanol to oil from 7:1 to 11:1, the biodiesel yield and biodiesel purity decreased. They also measured the biodiesel properties including acid value, density, kinematic viscosity, iodine value, acid value, saponification value, Cetane number, flash point, cloud point, pour point, and distillation characteristics. The properties of biodiesel were compared to standard biodiesel properties (ASTM 6751 and EN14214).

Abu-Hamdeh and Alnefaie 2015 [2] investigated performance and emission of diesel engine derived by almond biodiesel blending with diesel fuel. They prepared B10 (10% biodiesel with 90% diesel), B30 (30% biodiesel with 70% diesel) and B50 (50% biodiesel with 50% diesel) on Volume basis. They tested the diesel engine and found the result that At a fixed value of torque specific fuel consumption increasing with increasing blending percentage, brake thermal efficiency decreases with increasing blending percentage, emission of carbon monoxide decreases with increasing blending percentage, total particulate emission decreases with increasing blending percentage unburned fuel emission decreases with increasing blending percentage and NO_x emission increases with increasing blending percentage.

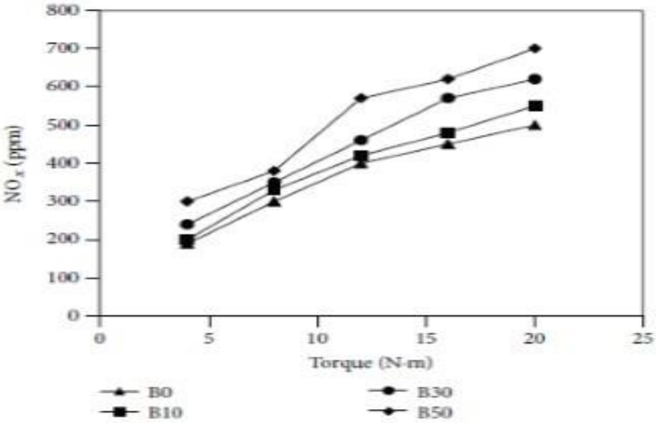

Figure 1: Variations of NOX concentration in the exhaust versus measured torque for fuels used in the study.

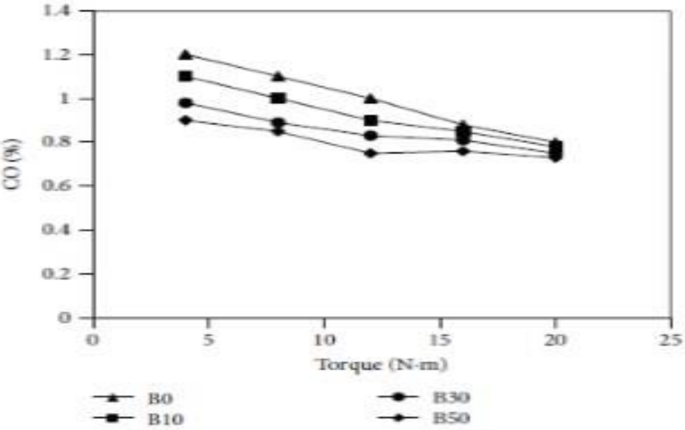

Figure 2: Variation of carbon monoxide concentration in the exhaust versus measured torque for fuels used in the study.

Venkanna and Reddy 2009 [16] examined the production of biodiesel from undi oil (Calophyllum inophyllum linn). A tree stage process (preheating, alkali-catalyzed transesterification and post treatment) adopted for the production of biodiesel. They studied and optimized the effect of different reaction parameters such as methanol to oil molar ratio, catalyst concentration, temperature and time. The maximum yield of biodiesel is found to be 89% under the optimized condition.

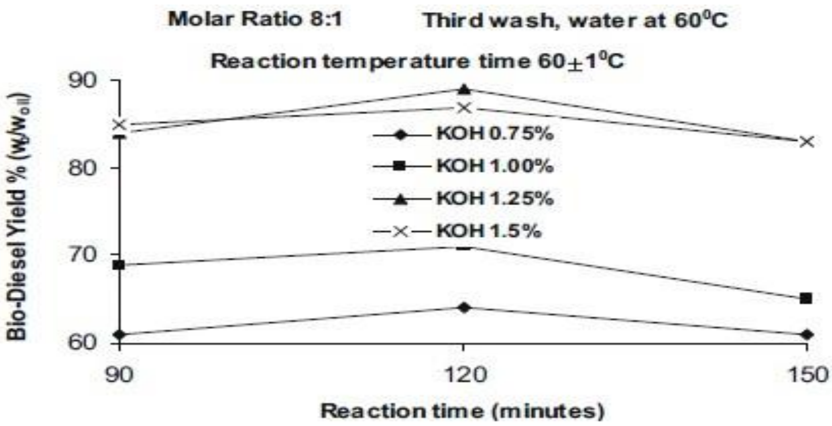

Figure 3: Effect of reaction time on biodiesel yield at different KOH concentration keeping other process parameter constant.

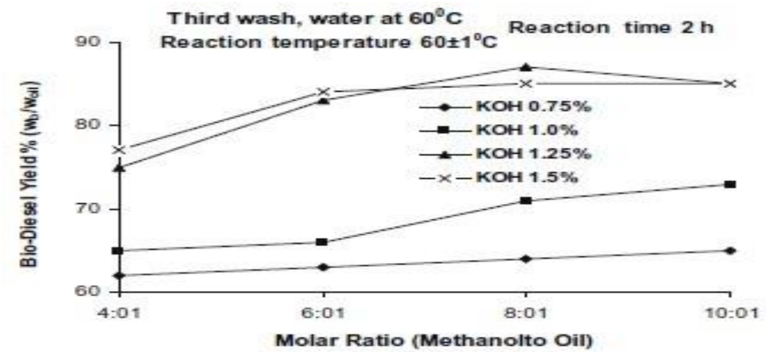

Figure 4: Effect of molar ratio (methanol to oil) on biodiesel yield at different KOH concentration keeping other process parameters constant.

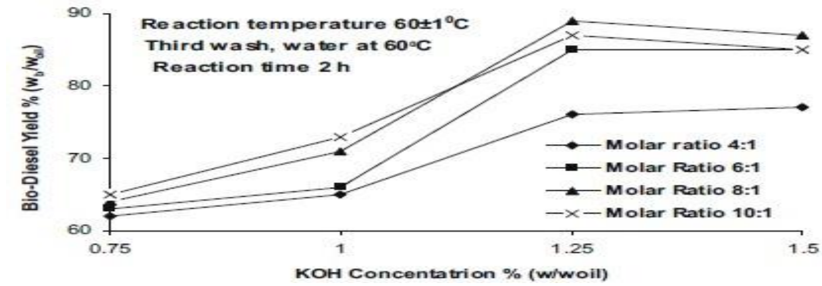

Figure 5: Effect of KOH concentration on biodiesel yield for different molar ratio (methanol to oil) keeping other process parameter constant.

Venkanna and Reddy 2015 [17] examined the combustion characteristics, performance and emission of a diesel engine running on blends of undi oil (Honne oil) with diesel fuel. The engine tested with fuel blends H10 (10% honne oil + 90% diesel fuel) to H50. The engine performance, emission and combustion characteristics of H20 blend fuel are found to be near value to diesel fuel, whereas higher blend ration are found to be inferior to diesel fuel.

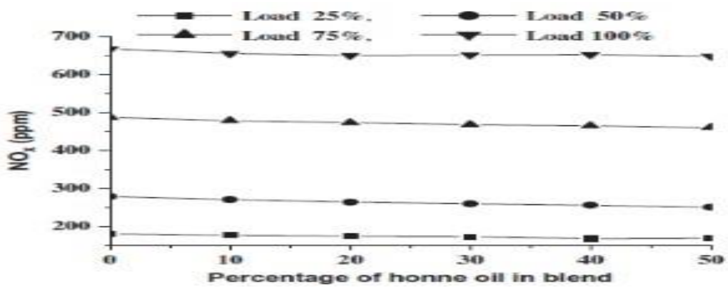

Figure 6: The effect of volume of honne oil in the fuel blend on NO_X at different load.

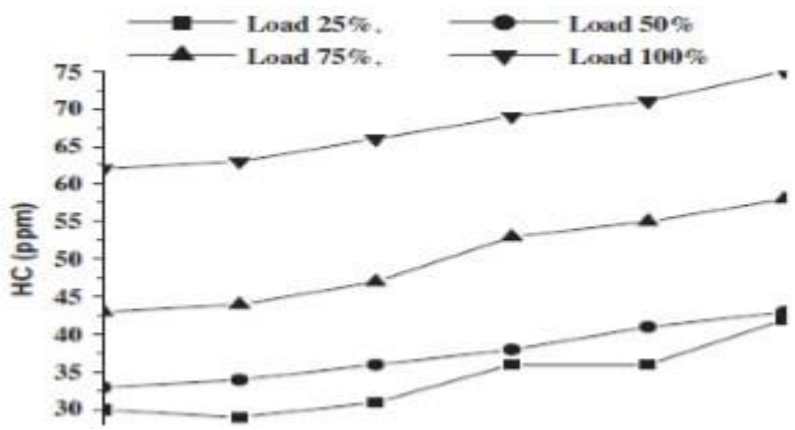

Figure 7: The effect of volume of honne oil in the fuel blend on HC at different load.

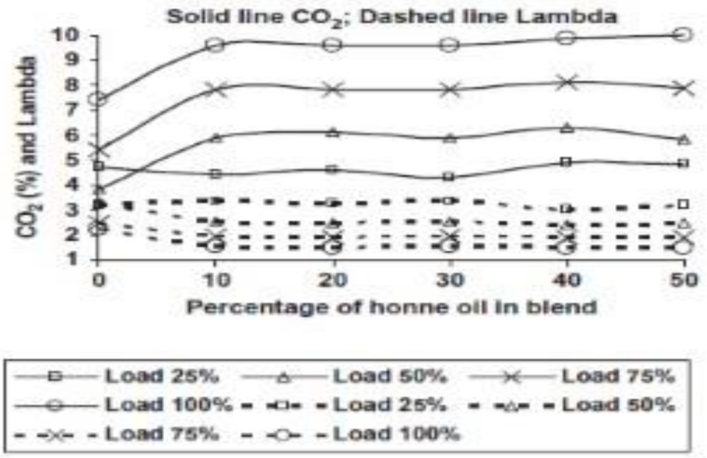

Figure 8: The effect of volume of honne oil in the fuel blend on CO2 and lambda.

Altun et al. 2008 [6] investigated the sesame oil is used as a fuel by mixing of 50% sesame oil with 50% diesel fuel. They compared the engine performance and exhaust emission characteristics of sesame oil-diesel fuel mixture with diesel fuel in DI diesel engine. The experimental results shown that amount of exhaust emission for the mixture of sesame oil and diesel fuel are lower than those of diesel fuel. For the mixture of sesame oil and diesel fuel, the engine power and torque value are near to the values obtained from diesel fuel.

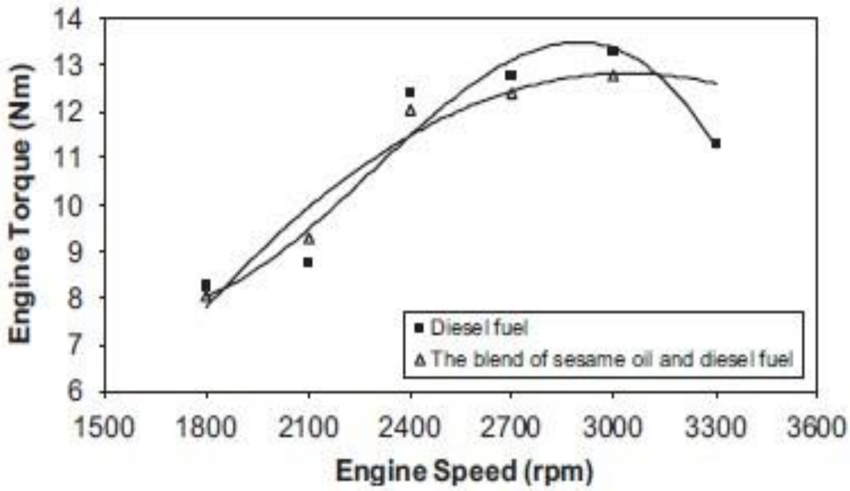

Figure 9: The variation of engine torque with engine speed for diesel fuel and for the blend of sesame oil and diesel duel.

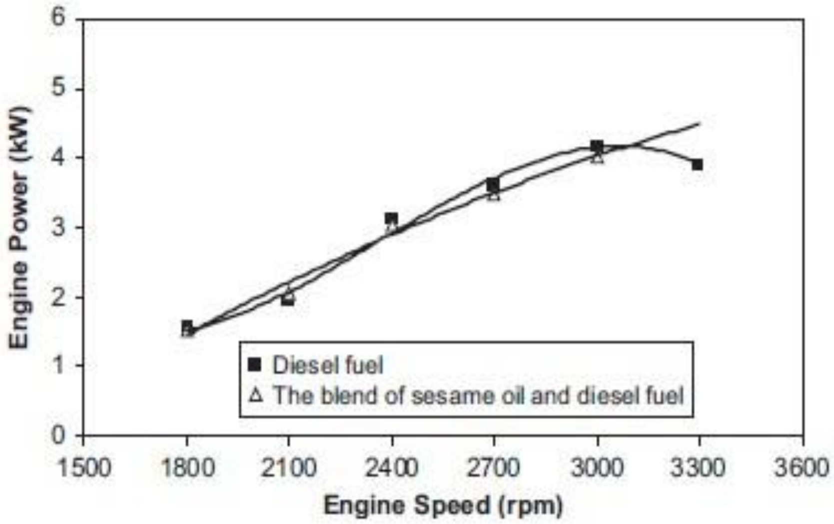

Figure 10: The variation of engine power with engine speed for diesel fuel and for the blend of sesame oil and diesel fuel.

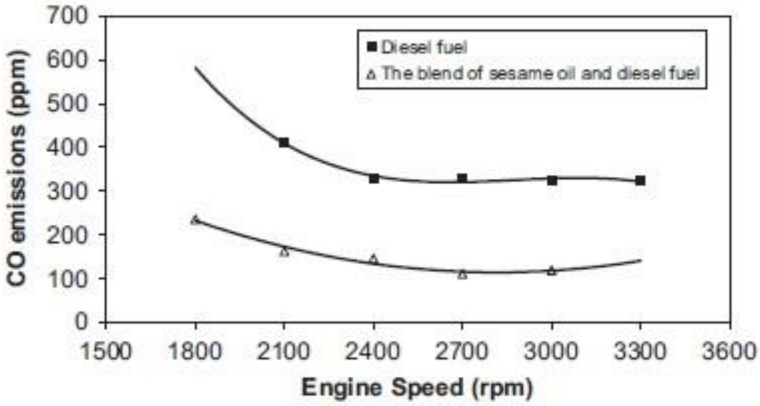

Figure 11: Comparison of CO emission of the blend of sesame oil and diesel fuel with those of neat diesel fuel.

Banapurmath et al. [9] studied the transesterification of Honga, Jatropha and Sesame oil to produce the biodiesel to use their biodiesel as an alternative fuel for DI compression ignition engine. This Engine was operated to evaluated Performance and emission characteristics from different fuel. Engine performance in terms of higher BSFC (brake specific fuel consumption) and lower emission (HC, CO) with sesame oil biodiesel operation was observed compare to other two biodiesel.

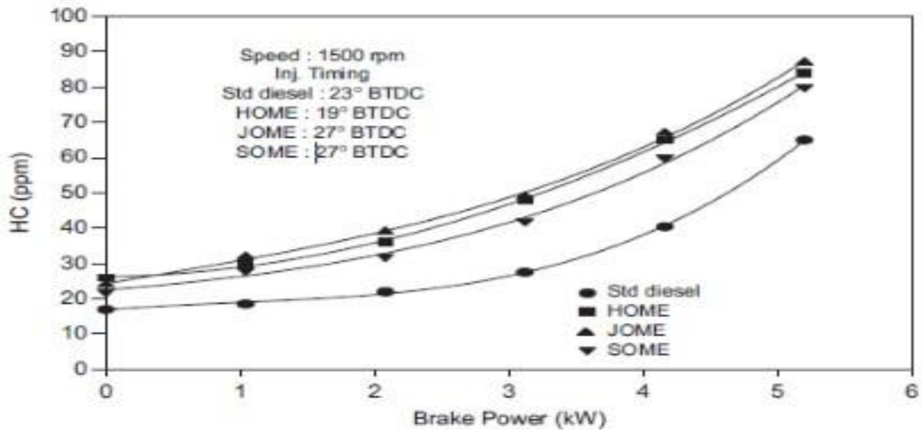

Figure 12: Effect of brake power on HC emission.

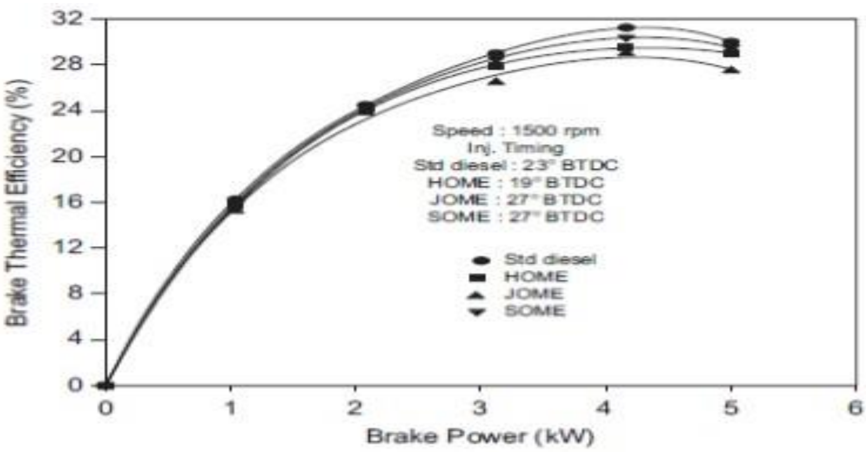

Figure 13: Effect of brake power on brake thermal efficiency.

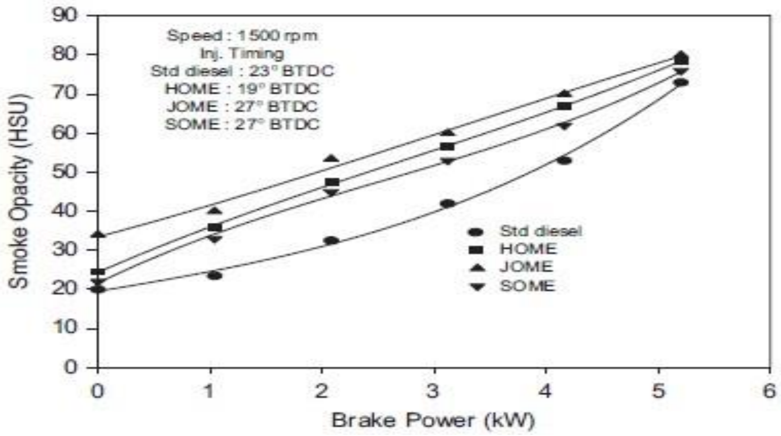

Figure 14: Effect of brake power on smoke opacity.

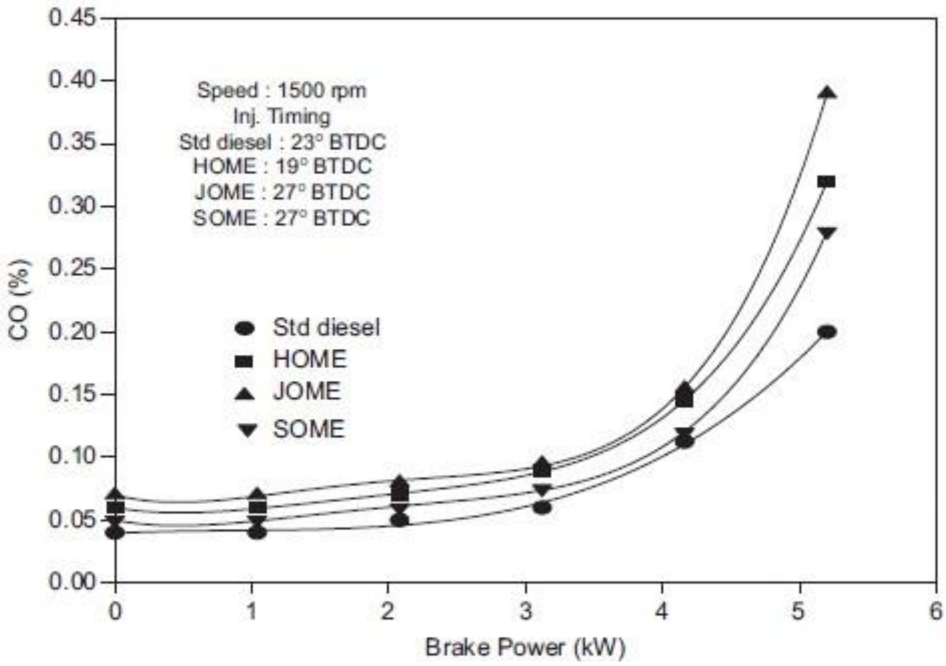

Figure 15: Effect of brake power on CO emission.

CONCLUSION

Biodiesel fuel has been gaining more interest as an attractive substitute of a diesel fuel due to the environmental pollution and diminishing of fossil fuel. Combustion characteristics of biodiesel fuel are similar to diesel fuel so that we can use the biodiesel in CI engine without any major modification. Biodiesel blend can reduce HC (hydrocarbons), smoke opacity, particulate matters, CO_2 (carbon dioxide) and CO (carbon monoxide) emission but slightly increased in NO_x emission.

Following summary can be drawn From the Study of above literature

1. Most of the authors showed that using biodiesel in diesel engine significantly reduce particulate emission, carbon monoxide and hydrocarbon due to higher oxygen content and higher Cetane number capered to with diesel fuel.
2. Most of the authors reported that NO_x emission increase while biodiesel is used in the CI engine. This is happened due to the higher oxygen of biodiesel which results in complete combustion and therefore higher combustion temperature.
3. Most of the authors reported that using biodiesel in diesel engines slightly lowered BP (brake power) and BTE (brake thermal efficiency) but increase brake specific fuel consumption (BSFC) than diesel fuel. Higher viscosity, density and lower heating value are the key factors for these issues.

Almond oil is edible oil. We can use it for biodiesel purpose. The purpose of biodiesel will not affect the supply of edible almond oil. In India sesame oil is generally used for biodiesel purpose. But almond oil biodiesel has better properties compare to sesame like as viscosity, flash point, calorific value etc.

REFERENCES

1. Abu-Hamdeh, N.H. and Alnefaie, K.A., 2014. Bio-Diesel from Almond Oil as an Alternative Fuel for Diesel Engines. In Applied Mechanics and Materials (Vol. 575, pp. 624-627). Trans Tech Publications.
2. Abu-Hamdeh, N.H. and Alnefaie, K.A., 2015. A Comparative Study of Almond Biodiesel-Diesel Blends for Diesel Engine in Terms of Performance and Emissions. BioMed research international, 2015.
3. Abu-Hamdeh, N.H. and Alnefaie, K.A., 2015. A comparative study of almond and palm oils as two bio-diesel fuels for diesel engine in terms of emissions and performance. Fuel, 150, pp.318-324.
4. Agarwal, A.K., 2007. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress in energy and combustion science, 33(3), pp.233-271.
5. Ahmad, M., Ullah, K., Khan, M.A., Ali, S., Zafar, M. and Sultana, S., 2011. Quantitative and qualitative analysis of sesame oil biodiesel. Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, 33(13), pp.1239-1249.
6. Altun, Ş., Bulut, H. and Oner, C., 2008. The comparison of engine performance and exhaustemission characteristics of sesame oil–diesel fuel mixture with diesel fuel in a direct injection diesel engine. Renewable Energy, 33(8), pp.1791-1795.
7. Atapour, M. and Kariminia, H.R., 2011. Characterization and transesterification of Iranian bitter almond oil for biodiesel production. Applied Energy, 88(7), pp.2377-2381.
8. Atapour, M. and Kariminia, H.R., 2013. Optimization of biodiesel production from Iranian bitter almond oil using statistical approach. Waste and Biomass Valorization, 4(3), pp.467- 474.
9. Banapurmath, N.R., Tewari, P.G. and Hosmath, R.S., 2008. Performance and emission Characteristics of a DI compression ignition engine operated on Honge, Jatropha and sesame oil methyl esters. Renewable energy, 33(9), pp.1982-1988.
10. Giwa, S. and Ogunbona, C., 2014. Sweet almond (Prunus amygdalus" dulcis") seeds as a potential feedstock for Nigerian Biodiesel Automotive Project. Revista Ambiente & Água, 9(1), pp.37-45.
11. Ong, H.C., Mahlia, T.M.I., Masjuki, H.H. and Norhasyima, R.S., 2011. Comparison of palm oil, Jatropha curcas and Calophyllum inophyllum for biodiesel: a review. Renewable and Sustainable Energy Reviews, 15(8), pp.3501-3515**.**
12. Ong, H.C., Masjuki, H.H., Mahlia, T.M.I., Silitonga, A.S., Chong, W.T. and Leong, K.Y., 2014. Optimization of biodiesel production and engine performance from high free fatty acid Calophyllum inophyllum oil in CI diesel engine. Energy Conversion and Management, 81, pp.30-40.
13. Saydut, A., Duz, M.Z., Kaya, C., Kafadar, A.B. and Hamamci, C., 2008. Transesterified sesame (Sesamum indicum L.) seed oil as a biodiesel fuel. Bioresource Technology, 99(14), pp.6656-6660.
14. Sharma, M.P., 2016. Selection of potential oils for biodiesel production. Renewable and Sustainable Energy Reviews, 56, pp.1129-1138.
15. Subramaniam, D., Murugesan, A., Avinash, A. and Kumaravel, A., 2013. Bio-diesel production and its engine characteristics—An expatiate view. Renewable and sustainable energy reviews, 22, pp.361-370.
16. Venkanna, B.K. and Reddy, C.V., 2009. Biodiesel production and optimization from Calophyllum inophyllum linn oil (honne oil)–A three stage method. Bioresource Technology, 100(21), pp.5122-5125.
17. Venkanna, B.K. and Venkataraman Reddy, C., 2015. Performance, Emission, and Combustion Characteristics of a Diesel Engine Running on Blends of Honne Oil and Diesel Fuel. International Journal of Green Energy, 12(7), pp.728-736.