

Study of Biodiesel (Surahonne and Cottonseed) as a Fuel for CI Engine with and Without Air Preheated and Fuel Preheated: a Research Review

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ABSTRACT: Today world alternative source of energy given importance due to gradual depletion of fossil fuel reserves. The vegetable oils can be used as an alternative to diesel in CI engines. The present review covers the various aspects of biodiesel fuel derived from Surahonne (*Calophyllum inophyllum* linn) and Cottonseed (*Gossypium*) oil. The major disadvantage of vegetable oil and their derivatives lies in their viscosity and cause the effect on engine performance. The review reported that the preheating is the most suitable technique along with blending among the methods used for viscosity reduction. The present review focussed on the recent works attempted for preheated vegetable oil and their derivatives, preheated air and the effect of preheating on the engine performance and emissions.

KEYWORDS: Surahonne oil, cottonseed oil, viscosity, air and fuel preheating.

I. INTRODUCTION

The fossil fuels used are non-renewable and due to continue use, they will deplete in the future and there will be energy crisis in the world. The use of fossil fuels also pollutes the environment. The developing countries like India and China, the consumption of petroleum products and natural gas increases year by year at unbelievable rate. Therefore bio-diesel is being considered to be alternative fuel to the diesel in the countries. The fuel produced from natural renewable sources such as vegetable oil, seeds and fats is the best alternative to present source of energy produced from fossil resource. There is a long list of trees, shrubs and herbs available plentifully in India, which can be used for extracting oil and producing bio-diesel as fuel from them. There are many plants in India however there are 77 non-edible Indian plants, which contain 30% or more oil in their seed fruit or nut [1].

1.1 General Aspects of *Calophyllum Inophyllum* Oil

Calophyllum Inophyllum (Punnaka), Punnakka oil is produced from the tree called punna which belongs to the family Clusiaceae and the tree is medium to large size with shining leaves and golden seeds. Punnakka oil is obtained by crushing the seeds and kernels are separated for drying in sun, the kernels of the seeds have high oil content of 75%. The Table 1 shows the properties of punnaka bio-diesel [1].

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Table 1: Properties of punnaka bio-diesel [1]

Property	Unit	Punnakka bio-diesel
Viscosity at 40 ⁰ C	Mm ² /s	5.6
Flash point	⁰ C	146
Acid value	Mg KOH /g	0.5
Calorific value	Mj/kg	37.5
Specific gravity	-	0.875

The Table 2 shows the properties Honne oil and hone oil methyl ester (HOME) as per the standards IS-1448 in comparison with diesel fuel.

Table 2: Properties of Honne oil, HOME as per the standards IS-1448) [2]

Parameter	Diesel	HOME	Honne Oil [2]	Calophyllum oil methylester [3]
Density at 15 ⁰ c(gm/cc)	0.835	0.8653	0.9363	0.892
Kinematic Viscosity at 40 ⁰ (cSt)	3.5	1.744	51.58	3.87 (at 30 ⁰ cSt)
Calorific value (MJ/kg)	43.00	35.37	40.27	-
Flash point (⁰ c)	44	8.5	220	176

As per the above Table 2, the kinematic viscosity of biodiesel (HOME) is lower than diesel fuel; hence bio-diesel shows good fluid ability characteristics and easily atomize to fine particles, hence better mixing with combustion air which help to improve combustion. Calorific value of biodiesel (HOME) is lower than diesel fuel, which directly affect the heat liberated in combustion of biodiesel fuel thus lower the power output. Flash point value of biodiesel (HOME) is lower than diesel fuel, which improves the formation of air fuel vapour mixture, which results into homogeneous combustion of biodiesel fuel [2]. Calophyllum inophyllum (nagchampa) tree grow to height of 8-20 m and also tree grows best in direct sunlight, but grows slowly. Annual yield of 20-100 kg/tree of whole fruits have been reported. Trees begin to bear significantly after 4-5 years. The nut Kernel Contains 50-70% of oil and the mature tree may produce 1-10 kg of oil per year depending upon the productivity of the tree and the efficiency of extraction processes. A use of the total calophyllum inophyllum tree has got excellent medicinal properties. The B20 blend gives efficient performance with lower emission (CO₂ and HC) [3].

Table 3 shows that the viscosity of honne oil is 32.47 cSt at 40° C where at 100° C the viscosity is 9.09 cSt. At high temperature the viscosity falls to below 10 cSt which reduces the atomization problem. Density of honne oil is slightly higher than neat diesel. Based on the experimental work with H100 at maximum load, Brake thermal efficiency of H100 is 25.01% compared to 29.20% with ND. Exhaust gas temperature of H100 is 620⁰ C compared 565⁰ C With neat diesel (ND). CO emission of H100 is 0.36% (by volume) compared to 0.15% (by volume) with ND. HC emission of H100 is 80 ppm (uL/L) compared to 62 ppm (uL/L) with ND. Smoke opacity of H100 is 95% compared to 84.8% with ND. Nox emission of H100 is 550 ppm (uL/L) compared to 667 ppm (uL/L) with ND [4].

Table 3: Comparison of Properties of diesel fuel Honne and few vegetable oils [4]

Properties	Units	ND	Honne Oil	Cottonseed oil	Soybean oil	Corn oil	Olive oil	Honge oil	Rice brain oil
Density at 15 ⁰ C	Kg/m ³	830	910	910	925	915	925	924	901
Kinematic viscosity 40 ⁰ C	cSt	3.12	32.47	34	33	35	32	45.23	42.55
Lower heating value	kJ/kg	43000	39100	36800	37000	36300	37000	30440	38952

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1.2 General Aspects of Cottonseed Oil

Cotton is a weather shrub or tree of the malvaceae family, the tribe Gossypieae and the genus gossypium that grows naturally as a perennial, but for commercial purposes it is grown as an annual crop. Botanically cotton bolls are fruits. The principal domesticated species of cotton of commercial importance are hirsutum, barbadense, arboeum and herbaceum. This variety is long staple cotton having a yield of 2-3 tonnes / hectare and a maturity of 130-140 days. The oil yield obtained was 15.05% and moisture content 7.21%. The low moisture content of the oil is advantageous in terms of storage stability since the lower the moisture content, the better the storability and suitability to be preserved for a longer period [5].

Table 4: Properties of diesel and Bio-diesel [6]

Sl. No	Perproperties	Diesel	Cottonseed	Neem Seed
1	Calorific value (kJ/kg)	43000	39648	35125
2	Flash point (° C)	44	234	178
3	Fire point (° C)	49	192	209
4	Viscosity (poise)	0.278	2.52	1.864
5	Density (Kg/m ³)	895	850	928

The Table 4 shows the properties of cottonseed methyl esters and neem seed along with diesel. They reduce the environment impacts of transportation and also reduce the dependency on crude oil imports and also provide employments in agricultural field. Properties of the 20% blend of some are nearer to the diesel Fuel [6]. The Table 5 shows the chemical properties cottonseed oil and jatropha oil in comparison with diesel fuel. In developing nations CSO is available in ample quantity. If it is processed as per the fuel requirements in mass production then there is a chance for reducing its overall cost. Then it will become a renewable source of energy in the case of diesel fuel scarcity [7].

Table 5: Chemical properties of cottonseed oil and jatropha oil in comparison with diesel fuel [7]

Sl. No	Properties	Cotton seed oil 100%	Jatropha (B100)	Diesel
1	Specific gravity	0.91	0.8621	-
2	Density (kg/m ³)	912	856	828
3	Flash point (° C)	207	174	56
4	Fire Point (° C)	230	180	63
5	Kinematic Viscosity cSt @ 40° C	55.61	5.37	2.68
6	Calorific value (MJ/Kg)	38	39.174	42.96

The Table 6 reported the comparison of brake thermal efficiency and indicated thermal efficiency for pure (B100) cottonseed and jatropa biodiesel. Diesel fuel contains different hydrocarbons (Benzene, tolene, xylences, etc) sulphur and contamination of crude oil residues. But chemical composition of biodiesel is different from the petroleum based diesel fuel. Biodiesel contains about 10% oxygen by weight biodiesel does not contain any sulfur aromatic hydrocarbons, metals and crude oil residues. These properties improve combustion efficiency and emission profile. Biodiesel fuel blends reduce particulate material (pm) Hydrocarbon, carbon monoxide and sulphur oxides. However NOx emissions are slightly increased depending on biodiesel concentration in the fuel. Due to the lack of sulphur biodiesel decrease, levels of corrosive sulphuric acid accumulating in engine crank case oil [7].

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Table 6: Efficiencies Comparison [7]

Sl	Properties	Cotton Seed oil (CSO)	Jatropha (B100)	Diesel
1	Brake thermal efficiency	16.61%	16.11%	14.69%
2	Indicated Thermal Efficiency	20.71%	20.13%	17.57%

Cottonseed oil is derived from the seeds of various species of cotton that are grown primarily for their fibers. The oil and protein contents of the seeds vary with the variety and agro climatic condition. Some varieties may have up to 25% oil content. The most important feature of this cotton seeds is that it grows in the form of climbing plant in sandy soil with in a six month crop cycle. As we know that availability of the raw materials controls the economics of the product [8].

The percentage oil content of the cotton seed kernel was determined using equation and it gave an oil content of 20.2%.

$$\% \text{ oil content} = \text{weight of oil extracted} / \text{weight of seeds kernel used} * 100$$

The value is low compared to the yield of other seeds but the resulting cake has economic value as is edible and can hence be used as animal feed concentrate [9].

Table 7: Fuel and physio-chemical properties of cottonseed & its biodiesel [9]

Property	Unit	Oil	Biodiesel
Specific gravity at 15 °C	Kg/m ³	0.92	0.91
Pour Point	°C	2	-1
Cloud Point	°C	13	6
Flash Point	°C	316	110
Fire point	°C	322	228
Kinematic Viscosity at 40 °C	mm ² /s	50.7	4.10
Lower Heating value	KJ/kg	41.25	39.54

Cottonseed oil because of the low free fatty acid does not require a two stage treatment for biodiesel production by alkaline transesterification, which is of economic values for large scale production [9]. The use of non-edible vegetable oils compared to edible oils is very significant, edible oils like rice bran oil and cotton seed oil are having tremendous potential as alternate fuels from the research and studies carried out in the past, it is evident that there are various problems associated with the use of vegetable oils as fuel in compression ignition engines, predominantly caused by high viscosity and poor volatility. Due to the high viscosity, the long term operation of the engine with vegetable oils normally introduce the development of gumming the formation of injector deposits ring sticking and problems related to the lubricating oils. The problem of high viscosity of vegetable oils can be reduced in several ways such as transesterification, micro emulsification preheating the oils and blending with other fuels such a diesel [10].

It is reported that, the 20-40% of cotton seed oil can be added to diesel and it can be used as a substitute fuel for diesel engines without any engine modification. The exhaust gas temperature was the highest for cottonseed oil and the least for diesel for all loads. This is due to the slow combustion of cottonseed oil due to the high viscosity and poor volatility. The reason of exhaust gas temperature being more in the case of biodiesel blends is the presence of more oxygen atoms in the biodiesel. The cotton seed oil gives slightly higher CO emission as compare to diesel. This is due to poor spray characteristics and improper mixing, resulting in poor combustion. Cottonseed oil results in higher HC emission compared to diesel. High viscosity leads to bigger fuel droplets and hence a non uniform distribution with air. Non uniform distribution will lead to too rich pockets that can result in HC [10].

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1.3 General Aspects of Preheating

For a long period heating induction system to assist fuel vaporization under the cold engine operation was employed. To legalize the above statement, numerous literature studies had been carried out. Among those the notable works are collectively organized and presented here.

1.4 General Aspects of Air Preheating

Yilmaz [11,12] investigated the effects of intake air preheating on the performance and emission trends of a diesel engine fueled with biodiesel alcohol blends. In the study the intake air was preheated to the upper limit of 85⁰c. Based on the study it was clearly suggested that complete combustion of bio diesel in a diesel engine could be guaranteed by operating the engine with bio-diesel alcohol. (Either methanol or ethanol) blends under warm environment [11].

1.5 General Aspects of Fuel Preheating

Roheman et al.[13] investigated the effects of preheating jatropha oil by means of residual gas exhibited greater influence on the performance and emission characteristics. For the purpose of preheating, a helical coil heat exchanger was fitted to raise the temp of Jatropha oil and the inlet temperature of the oil was maintained within a range of $\pm 70^{\circ}$ C throughout the mode of engine operation. Overall the experimental results indicated lower BTE and higher fuel consumption for preheated Jatropha oil when compared to neat diesel operation. On the other hand the reduced emission trends were also witnessed due to preheating.

Another investigation on the effect of fuel preheating was critically evaluated by Hazar and aydin,[14] in the study the performance and emission behaviour of a CI engine fuelled with preheated rapeseed oil-diesel blends were explored. Hazar and Aydin elucidated in their work that the use of preheated oil-diesel blends would offer smooth fuel flow with total evasion of fuel filter clogging. This trend was primarily accomplished in their study by preheating the coil to 100⁰ C. Also the study clarified that the effect of preheating fuels tends to lower the power output as the results of higher leakages in the pump and injector [15].

Transesterification, pyrolysis is the processes generally performed in order to reduce the viscosity of biodiesel but still it is higher to that of the diesel. Thus preheating is the technique to decrease viscosity of the biodiesel.

II. LITERATURE SURVEY WITH AIR PREHEATING AND FUEL PREHEATING

Lots of research works were conducted to examine the engine performance and exhaust emissions using preheated vegetable oils. Barsic et al.[16] have indicated that it is essential to preheat the vegetable oil to 70-90 ⁰ C to resolve the fuel filter clogging problem. Ryan and his co-workers have specified a fuel inlet temperature requirement at 140 ⁰ C for acceptable viscosity for using vegetable as fuel for both direct injection and indirect injection engines. It was reported that heated the vegetable oils to 140⁰ C would (1) reduce the viscosity to near that of diesel at 40⁰ C (ii) Increase the cetane rating (iii) improve the spray characteristics by increasing the penetration rate accompanied by decrease in cone angle. Bari et al have showed that preheating of crude palm to 60⁰ C is essential to lower its viscosity, ensure smooth flow and to avoid fuel filter clogging. It was also indicated that the injection system was not affected even by heating to 100⁰ C. The studies were carried on transesterification process which decreases effect on the viscosity of vegetable oil biodiesel still has higher viscosity and density when compared with diesel fuel. Investigation have shown that B20. Blend has good performance and emission characteristics on CI engine.

Preheating process involves heating of biodiesel before injecting it into combustion cylinder. Biodiesel can be preheated at different temperature of 60⁰ C, 90⁰ C, 120⁰ C and 150⁰ C. But the case study on preheating temperature have found that preheating temperature for biodiesel should be 90⁰ C to meet above mentioned characteristic requirement. Murat karabektas reported that the specific gravity and kinematic viscosity of the cottonseed oil Methyl Ester (COME) gradually decrease with the increase in preheating temperature. It is seen that the kinematic viscosity is 6.54 cSt at 30⁰ C and decreases gradually to 1.26 cSt at 120⁰ C. Additionally the specific gravity decreases from 0.882 at 30⁰ C to 0.851 at 120⁰ C.

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Table 9: Effect of preheating on different oil properties [12].

Properties	Diesel	Jatropa oil	Cottonseed oil	Rice brain oil
Kinematic viscosity (cSt)	2.25	Without preheating 35.9	Without preheating 5.49	Without preheating 5.49
		After preheating at 120 °C 5.82	After preheating at 120 ⁰ C 1.26	After preheating at 120 ⁰ C 1.26
Cetane number	48	52	-	56.2
Density gm/cc	0.82	0.88	0.82	0.78

Dhinagera et al.[17] tested neem oil , rice brain oil and karanji oil on low heat rejection engine. An electric heater was used to Heat of the oil. The exhaust gas was also utilized for heating the oli without heating 1-4% lower efficiency was reported compared to that of diesel. Masjuki et al[18] used preheated palm oil to run a compression ignition engine. Preheating reduced the viscosity of fuel and hence better spray and atomization characteristics were obtained. Torque, brake power, Specific fuel consumption, exhaust emission and brake thermal efficiency were found to be comparable to that of diesel. COME (Cottonseed Methyl Ester) can be used in CI engines without making any changes in engine. The major technical problem of viscosity, density can be effectively eliminated by heating biodiesel before injecting it into combustion chamber. They also reported that:

- Preheating of biodiesel effectively decreases the kinematic viscosity, density and surface tension properties which dominantly improves injection of biodiesel by contributing to better fuel atomization at the elevated temperature of the biodiesel.
- Moreover preheating reduces the ignition problem by decreasing the ignition delay during cold start of engine in cold counties.
- Preheating contributes to reduction in CO, CO₂ emissions of biodiesel than that of the pure diesel and un preheated biodiesel while the NO_x emission increases with increase In preheating temperature due to increase in combustion temperature [19].

Heating of the cottonseed (the upper limit of fuel inlet temperature tested was 80⁰ C) Biodiesel with additive [Ac2010a (Butylhydroxytoluene)] prior to injection into the engines combustion chamber results in a reduction in viscosity, leading to better atomization and improved performance and reduce emissions. Results revealed reduction in NO_x emission with fuel preheating. This is due to lower ignition delay caused by increase in fuel inlet temperature. Easy vaporization and better mixing of air and fuel occur due to warm up of the inlet fuel which causes lower Co emission. Uniform or better combustion is occurred due to preheating of inlet fuel, which results in lower engine noise. The blend of B20 diesel by is found to give optimum performance [20].

The engine performance and emission tests were conducted with diesel fuel, mahua oil and mahua oil preheated to 130⁰C. In this investigation a temperature of 130⁰C was maintained for preheating mahua oil flowing through the high pressure fuel line with the help of a manually operated electrical heating arrangement. It is seen that the viscosity was reduced to 4-6 cSt at 130⁰C and found to be almost equal to diesel at 40⁰C. In order to maintain the engine speed constant at 1500 rpm, the flow rate of mahua oil was reduced by adjusting the fuel injection pump control rack. All the observations were taken for 0%, 25%, 50%, 75% and 100% of full load on the engine. It is seen that the HC emission was lowered for mahua oil combustion with preheating. Preheating caused more complete combustion of mahua oil. The HC emission was 85ppm with preheating compared to mahua oil (140ppm) and diesel (120ppm) full load. It is seen that the co concentration reduced significantly with preheating mahua oil. It was reduced from 0.4% with mahua oil to 0.36% with preheating mahua oil to 130⁰C. The NO_x concentration at maximum load increased by 13% with mahua oil preheated at 130⁰C compared to mahua oil without preheating. However the NO_x emission was significantly lower with preheated mahua oil compared to diesel at all power outputs. Mahua oil preheated to 130⁰C gives higher thermal efficiency, preheating to 135⁰C gives lower smoke and HC emission compared to that of diesel [21].

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The vegetable oil has fixed oxygen in it which can enhance the combustion process. A preheating of vegetable oil increases the poor cold flow properties and improves the atomization of fuel. Based on the reviewed paper for the performance and emissions of preheated vegetable oil, it is concluded that the preheated vegetable oil represents a good alternative fuel for diesel and therefore must be taken into consideration in the future for transport purpose. Except NO_x the other emission characteristics such as HC, CO and CO₂ are decreased due to preheating of the fuel. Preheating by exhaust gases could be one feasible solution to overcome the problem of high viscosity which is being the major cause of many problems identified by several researchers [22].

In the present work an experimental investigation is carried out on a four stroke single cylinder CI engine to find out the performance and emission characteristics with preheated B40 blend of Pongamia biodiesel and B20 biodiesel. The B40 blend is preheated at 60, 75, 90 and 110° C temperature using waste exhaust gas heat in a shell and tube heat exchanger. Transesterification process is used to produce biodiesel required for the present research from raw pongamia oil. It is observed that B40 blend has higher brake thermal efficiency at 110° C preheating temperature compared to other temperatures and B20 blend. It is showing increasing trend in BTE with increasing preheat temperature. The significant improvement in BTE is observed only after 50% loading. As the preheating temperature increases from 60° C to 110° C viscosity of blend decreased sharply and volatility of molecule increased. It has favourable effect on atomization and vaporization of fuel. The maximum thermal efficiency was found to be 38.83% at 110° C at 75% loading following 37.87%. BSEC for 110° C at 75% and full load are 9.95 MJ/KW-hr and 9.51 MJ/KW-hr respectively. For 110° C preheated B40 blend 2.79 and 2.14 MJ/KW-hr decrease in BSEC values are obtained over B20 blend for 75% and full load. The maximum reduction of UBHC over B20 blend is 78.12% for B40 blend at 110° C. The maximum NO_x emission is 1390 ppm and 1680 ppm for 110° C preheated B40 blend for 75% and full load. 73.14% reduction in smoke opacity is obtained for 110° C preheated B40 blend over B20 blend for 75% load. 62.5% and 66.67% reduction in CO emission is obtained for 110° C preheated B40 blend over B20 blend for 75% load and full load [23].

Experiments are carried out at the rated speed of 1500 rev/min with variable load conditions. In this work effect of fuel preheating using animal fat as fuel in a diesel engine is investigated. A separate heater arrangement is made to preheat the neat animal fat. The fat is heated at 30° C, 40° C, 50° C, 60° C and 70° C. Experiments are conducted at all temperatures. A separate heater arrangements is made to preheat the fat before it is injected into the engine. The heater arrangement is made in such a way that it can heat the fat throughout the entire path of its travel. The following conclusions are made based on the experimental results. They also reported that:

- Peak pressure and rate of pressure rise are lower with animal fat at low temperature as compared to diesel. They increase with increased fuel inlet temperature.
- Ignition delay is higher with animal fat as compared to diesel at all power outputs with fuel preheating there is a reduction in ignition delay.
- Lower heat release rates are found with animal fat as compared to diesel during the premixed combustion phase. However fuel preheating increased the heat release rates.
- Neat animal fat results in increased exhaust temperature as compared to neat diesel. It increases further with fuel preheating. Highest exhaust gas temperature is found with animal fat at 70° C
- Smoke density is low (3.6 k) with the animal fat as compares to diesel (6.5k) at 30° C. *It is further reduced with fuel preheating.* The lowest smoke level was found has 1.7k with animal fat at the temperature of 70° C.
- Hydrocarbon emission and carbon monoxide emissions are higher with animal fat as compared to diesel. However, fuel pre heating reduces these emissions.
- Low levels of NO_x emissions are found with animal fat at normal temperature fuel pre heating increases these emissions [24].

Diesel efficiency depends on multiple complex parameters like heat losses during cooling of engine, heat losses in exhaust gases, friction loss transmission efficiency losses etc. However intake air temperature plays a predominant role in achieving better efficiency. Air intake pre-heaters (also known as grid and manifold heaters) are used in diesel applications needing quick, reliable and environmentally friendly starts. Air intake heaters are installed in the intake

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manifold and pre-heat the combustion air to the required temperature for ignition of fuel. Air intake heaters reduce white smoke (cold emissions) engine wear, better consumption and fuel consumption during start up lower temperature intake air leads to inadequate final compression temperature, increase in emission delay, longer time between the injection of the fuel to ignition, local over – enrichment, incomplete combustion and high pressure gradients due to abrupt mixture conversion in the cylinder.

A warm air intake is better than a cold air intake on a diesel engine. A warm air intake improves fuel economy on a gas engine for 3 reasons.

- The warm air is less dense, so the throttle opens up more to get the same air, therefore throttling losses are reduced.
- The warm air improves the flame speed.
- The warm air improves the vaporization of the fuel.

Diesel engine was run without switching on the electrical heater and parameters were logged – first engine was run and data were collected without switching on the heater when the ambient temperature is 35°C. Then heater was switched on and heater outlet temperature was maintained at 45°C, 50°C and 55°C at two different loads viz 53.955 N & 93.195. At each stabilization step, parameters CO, UBHC, CO₂, O₂ & NO_x were logged. The following observations were made from the test.

- The heat input required for the engine reduces with increase in intake air temperature. This was observed in both loads.
- Since heat input reduces with in intake air temperature for the same load. Brake thermal efficiency increases.
- CO content in the exhaust gas slightly reduces with increase in intake air temperature.
- CO₂ & O₂ content in the exhaust gas remains unaltered in the exhaust with increase in intake air temperature.
- Whereas NO_x content in the exhaust gas slightly increases with increase in intake air temperature.

From the test it is clear that the fuel consumption reduces and brake thermal efficiency increases with increase intake air temperature. The CO₂ and O₂ content remains unaltered [25].

A waste heat loss arises both from equipments inefficiencies and from thermodynamic limitations on equipments and processes. For example, consider internal combustion engine approximately 30 to 40% is converted into usefull mechanical work. The remaining heat is expelled to the environment through exhaust gases and engine cooling systems. It means approximately 60 to 70% energy losses as a waste heat through exhaust (30% as engine cooling system and 30 to 40% as environment through exhaust gas). Exhaust gases immediately leaving the engine can have temperatures as high as 450 - 600°C. Consequently, these gases have high heat content, carrying away as exhaust emission. Efforts can be made to design more energy efficient reverberatory engine with better heat transfer and lower exhaust temperatures. However the law of thermodynamics places a lower limit on the temperature of exhaust gases. Experimental results on an order of efficiency properties of engine setup with IAP (Inlet air pre heater) are greater than efficiency properties of without IAP [26].

Chirtravelan M et al.[27] have experimentally proved that the effect of preheated air on standard diesel fuel engine indicated a good result on emission control. NO_x and CO emissions at intake air temperature of 55°C where less when compared at intake are temperature of 32°C result are proved from this experiments like that higher inlet air temperature will be affect some factors (a) lower ignition delay (b) lower NO_x formation (c) uniform or better combustion (d) lower engine noise (e) easy vaporization (f) better mixing a air and fuel occur due to warm up of inlet air (g) lower CO emission. The heat input required for the engine reduces with increase in intake air temperature. Fuel consumption reduces and brake thermal efficiency increases. CO content in the exhaust gas slightly reduces with increase in intake air temperature. CO₂ & O₂ content in the exhaust gas remains unaltered in the exhaust with increase in intake air temperature NO_x content in the exhaust gas slightly increases with increase in intake air temperature [28].

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Air preheating is a technique to increase the temperature of inlet air by utilizing the thermal energy of exhaust gas with a prime objective of increasing the thermal efficiency of the engine. Air preheating not only improves overall efficiency of the engine but also act as an emission control technique. Preheating of fuel improves the flow property of fuel such a viscosity and density of fuel. Also preheating increases the combustion efficiency by reducing the ignition delay and prolongs flame front propagation. The brake specific fuel consumption decrease with increase in fuel inlet temperature [29].

III. CONCLUSIONS

The following are the concluding remarks made from the recent works done on the preheating of air and fuel along with the general aspects and properties of Calophyllum Inophyllum oil and cottonseed oil and their derivatives.

- The viscosity of honne oil is 32.47 cSt at 40° C where at 100° C the viscosity is 9.09 cSt. At high temperature the viscosity falls to below 10 cSt which reduces the atomization problem
- 20-40% of cotton seed oil and Calophyllum Inophyllum oil can be added to diesel and it can be used as a substitute fuel for diesel engines without any engine modification.
- The specific gravity and kinematic viscosity of the cottonseed oil Methyl Ester (COME) gradually decrease with the increase in preheating temperature. It is seen that the kinematic viscosity is 6.54 cSt at 30° C and decreases gradually to 1.26 cSt at 120° C.
- Heating the vegetable oils to 140° C would [1] reduce the viscosity to near that of diesel at 40° C (ii) Increase the cetane rating and improve the spray characteristics by increasing the penetration rate accompanied by decrease in cone angle.
- Based on the reviewed paper for the performance and emissions of preheated vegetable oil, it is noted that the preheated vegetable oil represents a good alternative fuel for diesel and therefore must be taken into consideration in the future for transport purpose.
- It is observed that B40 blend has higher brake thermal efficiency at 110° C preheating temperature compared to other temperatures and B20 blend. As the preheating temperature are increases from 60° C to 110° C viscosity of blend decreased sharply and volatility of molecule increased. It has favourable effect on atomization and vaporization of fuel.
- A warm air intake is better than a cold air intake on a diesel engine. A warm air intake improves fuel economy on a gas engine for 3 reasons.
 - The warm air is less dense, so the throttle opens up more to get the same air, therefore throttling losses are reduced.
 - The warm air improves the flame speed.
 - The warm air improves the vaporization of the fuel.
- Preheating of fuel decreases its kinematic viscosity, specific gravity and surface tension properties which dominantly help in better injection of fuel.
- The BSFC is decreased with increase in fuel inlet temperature while BTE increases.
- Preheating reduces the ignition delay thereby improving cold start of engine in cold conditions; also shorter ignition delay leads to higher in cylinder pressure.
- Rise inlet temperature will improve combustion reactions and due to this efficiency, torque and break power of the engine improves.
- Due to better evaporation and shorter ignition delay engine produces low noise and vibration.
- Preheating of fuel and air subsequently reduces the exhaust emissions. HC & CO emission will decrease with increase in the inlet temperature while preheating has negative impact on NOx emission as it increases with increase in inlet temperature.

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