

# A Review on Variable Compression Diesel Engine with Turmeric Leaf Oil-based Biodiesel

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**Abstract**— The rapid depleting ores of petroleum, sharply escalating fuel prices and the environmental problems have triggered the need of alternatives and renewable energy sources. The situation is even graver in developing countries such as India. Currently, India ranks the second largest by population in the world as well as places herself second in the list of petroleum consumers. India imports 70% of the required fuel and spends around 30% of her foreign exchange over it. Besides that, transportation and agricultural sectors are major consumers of fossil fuels as well as biggest contributors to pollution, too. This has forced the individuals to search for alternatives in order to overcome the consequences of the conventional fuels.

Presently, a lot of researches have been carried out over the performances of various alternatives to evaluate their eligibility to partially or completely replace the conventional fuels. Though a lot of research is carried over various alternatives like ethanol, alcohols, cottonseed oil, palm oil, jatropha oil, mustard oil, etc., there has been no such promising alternative yet which can replace diesel, leaving a huge scope in this area. This paper describes yet another experimental investigation to search for the promising alternative to diesel. It comprises of the turmeric leaf biodiesel blended in varying proportions with diesel and at varying compression ratios. The results consist of the investigation of various performance parameters based on varying load conditions and its effect over the emissions. These results are then compared with the performance of neat diesel to prove its eligibility.

**Keywords**— Biodiesel, turmeric leaf oil, variable compression ratio, diesel engine, emissions, alternate fuels, performance, combustion

## INTRODUCTION

India is abode of 1.3 billion people which is 17% of the total world population having rapid growing thirst for energy. For the last two decades, there has been a tremendous increase in demand of conventional fossil fuels for engine, especially gasoline and diesel. The ores of these fossil fuels are quoted to become extinct in a couple of decades. This is leading to rapid increase in the costs and as well as the consequences of global warming. Only a few countries have reservoirs of usable fossil fuels and thus countries like ours have to be dependable on them. According to the Statistical Review of World Energy (2010), India produces 826000 barrels of oil per day and requires 3319000 barrels per day. This is a huge energy gap that needs to be bridged. These have freed us with liberty to try alternatives to diesel.

Thinking of the gaseous fuels, hydrogen appears to be the most promising one in future as it yields the highest amount of energy on combustion. Also it produces only energy and water when burnt. The consequences at current moment are its production, storage, distribution and transportation problem. These are claimed to be solved by 2020. While considering the liquid fuels, alcohol fuels are easy to produce. These are produced by fermentation of crops like corn. But, alcohols are highly corrosive and require certain expensive replacements in existing parts. Also, compatibility is another problem, as they may have certain effects. For an instance, production of corn-based ethanol has created an increased demand for feedstock, causing increased prices in all that is made from corn. So, we remain left to experiment with the biodiesels.

## BIODIESEL

More than a century ago, Rudolf Diesel had predicted that plant oils could be used in engines. Biodiesel can be stated as a fuel that is made up of a mono alkyl ester of a long chain of fatty acids that are derived either from vegetable oil or animal fat. Vegetable oils have good ignition quality as they have very long chained structures which are not branched. Inversely, the higher composition of oxygen content, carbon residue and larger molecular mass makes the heating value of biodiesels significantly lower than diesel. They have higher flash point and are around 10% denser than diesel, making them safe to store. But these have higher cold point causing them to thicken or even freeze at low ambient temperatures. Their poor volatility due to higher viscosity is responsible

for their lower cetane numbers. Further, biodiesels are biodegradable and reduce the CO<sub>2</sub> cycle. Also, they do not contain sulfur and any carcinogens, thus they are not harmful to living beings. An associated problem could be that, growing crops requires lot of time and high investment and transportation to local stations which makes the more expensive than diesel.

#### **Benefits of biodiesel**

- The combustion of biodiesel causes 80% less CO<sub>2</sub> emissions and no sulfur dioxide.
- The proportion of unburnt hydrocarbons is reduced by 90% of unburned.
- It is totally non-toxic and biodegradable.
- It has almost similar cetane number as that of diesel.
- Also, it imparts relatively better lubricity.

#### **Disadvantages of biodiesel**

- The biodiesel acts as an excellent solvent and thus the deposits at the filter section could get dissolved into it. This may cause severe degradation of engine parts.
- The biodiesel can cause problems in winter as the cold point is relatively higher as compared to the diesel. This means that the fuel can solidify and choke up the engine.

#### **LITERATURE SURVEY**

Mr. S. I. Meshram worked over the turmeric leaf biodiesel and found that when the turmeric leaves oil was used the engine power slightly decreased for all engine speeds. The loss of power occurred because of the lower calorific value. A brake thermal efficiency of engine with turmeric leaves oil is found to be slightly less as compared to gasoline. The brake specific fuel consumption for lower engine speed is more. The CO and HC concentrations using turmeric leaves oil was decreased by 13.7% and 16.94% respectively in comparison to gasoline, while the NO<sub>x</sub> concentration was increased by 10%.

Dr V. Naga Prasad Naidu, Prof. V. Pandu Rangadu, Krishna Reddy, R. Anand, G. R. Kannan, K. Rajasekhar Reddy and S. Velmathi investigated the use of cottonseed oil as biodiesel over a 4-stroke compression ignition engine in two different experimental setups and working conditions. The blending ratio was varied within a range of 5-40%. Both the experimentations concluded that the brake thermal efficiency was more for diesel, but the emissions were much reduced by the use of biodiesel. This happened because the oxygen content in biodiesel is higher, thus ensuring closer to complete combustion. They also found that, the biodiesel with 20% blending ratio earned to be the most economical one. It resembled the performance of diesel with lower emissions. Sunilkumar Kumbhar tried thumba oil over a variable compression ratio diesel engine. He observed that, at compression ratio 18, the brake thermal efficiency and brake specific fuel consumption for 10% blend and 20% blend while brake power with 40% blend showed better performance. The HC, CO and NO<sub>x</sub> emissions were least for the 10% and 20% blend, thus proving best.

N. Manikanda Prabu, Dr. S. Nallusamy K. Thirumalai Ra, Pavanendra Kumar, Niraj Kumar, Vineet Tirth, Sejal Narendra Patel and Ravindra Kirar and Hani Chotai investigated the use of jatropha seed-based oil over the 4-stroke diesel engine and observed the performance and emission characteristics. The compression ratio 18:1 showed the better experimental results for diesel as well as blends with least fuel consumption during the blending ratio of 20%, while the exhaust gas temperature, which is the indication of effectiveness of utilization of heat energy, was the most with the blends whereas, pure diesel giving the least exhaust temperature. The pure biodiesel being used showed the highest exhaust gas temperature, which means it exhibited highest brake thermal efficiency. But the problem associated with this was that, the engine would be modifies to the compression ratio of 20 or above. The emissions showed lower amounts of CO, CO<sub>2</sub> and HC when compared with the exhaust gases using pure diesel, while the NO<sub>x</sub> was inherently slightly higher because of higher oxygen content and exhaust gas temperature using biodiesel. Conversely, in other experimentation, the fuel with 50% blend showed the least emissions in expense to the performance characteristics of engine.

Ramchandra S. Jahagidar Eknath R. Deore, Milind S. Patil, Purushottam S. Desale executed an experimentation over the performance diesel engine fueled with karanja biodiesel. He tested different fuel blends of karanja biodiesel, pure diesel and pure karanja biodiesel. Results showed that the brake power of the engine did not vary much with any of the fuel combinations and was almost same for all the loads. However, brake thermal efficiency was improved for the karanja biodiesel from 3 to 8% along with volumetric efficiency, but it caused reduction in exhaust gas temperature. It was also observed that the blends of 40% and 60% had the optimum performance for the given conditions.

Similarly, the experimentations have been carried over the bio-products such as soya-bean seed, canola oil, tamanu seed, jujube seed, mahua oil, fish oil, and palm oil, mixtures of two or more oil-based biodiesels. More of these are easy to cultivate, cheap in cost, less attention for farming.

A. K. Azad, S. M. Ameer Uddin and M. M. Alam investigated whether it is feasible to experiment over a diesel engine using the biodiesel with and without trans-esterification process. For this purpose, the mustard oil-based biodiesel was used. When the chemical properties of the two samples, i.e. one with trans-esterified biodiesel and other without it, were tested, it was observed that the biodiesel without trans-esterification process had higher viscosity, density and moisture content and lower calorific heat content as compared to the other. When the experimentation was carried out, it was observed that, the heating value of the biofuel gradually tended to reduce with increase in bio-fuel blends. At low load conditions, the bio-fuel blends had higher brake specific fuel consumption than diesel. But, as the load was increased and the blend ratio was raised to 30%, it was seen that the brake specific fuel consumption was least. Also, the fuel without the trans-esterification process showed higher brake specific fuel consumption than the other one.

## TURMERIC LEAF OIL

### i. Production of turmeric

Turmeric is cultivated in India, China, Myanmar, Nigeria and Bangladesh. However, authentic figures about area and production are not available. Major production area is in India which constitutes 82% followed by China (8%), Myanmar (4%), Nigeria (3%) and Bangladesh (3%). The main turmeric producing states in India are Andhra Pradesh, Tamil Nadu, Orissa, Karnataka, West Bengal, Gujarat and Kerala.

Table 1: Area and production of turmeric in India

Year	Area (in hectares)	Production (in tonnes)
2008-09	162.9	552.3
2009-10	149.8	526.4
2010-11	150.7	567.2
2011-12	158.4	718.1
2012-13	177.5	846.7

The biological name of turmeric is *Curcuma Longa*. The rhizomes of *C. Longa* are preferably used in Indian systems for medical purposes, such as antiseptic, carminative, stomachic, appetizer, etc. It also finds its widest use as a constituent of food curry powders and food colourant but not as a condiment due to its bitterness. Its aroma has also been used to cure pimples, skin whitening as well as blood purification. The leaves of *C. Longa* have been observed to be a waste product which has traditionally been used for culinary preparation which are aromatic and contain oil. The leaves were cut into small pieces and hydro-distilled; major volatile constituents were identified under the chromatogram. These showed 1.32% of essential oil containing  $\alpha$ -phellandrene 38.24%,  $C_8$ -aldehyde 20.58%, 1,8-cineole 8.64,  $\alpha$ -pinene 2.88% and  $\beta$ -pinene 2.36%. Out of these,  $\alpha$ -pinene and  $\beta$ -pinene are the hydrocarbons and these burns in the process of combustion. Earlier, it was reported that the turmeric leaf oil is mixture of ketones and alcohols. In later studies, it was seen that the main constituent is phenol, which is a kind of alcohol. Moreover, the local experiences show that turmeric leaves are readily explosive, which proves it to have higher calorific content. In spite of this, the use of turmeric leaf oil has been less used for the purpose of producing heat energy in automobiles.

Nilesh Mundle, a pharmacy student from eastern Maharashtra advocated the use of turmeric leaf oil as possible alternative for biodiesel. He posted a related article when he found that the leaves could burn easily. This clicked that the turmeric leaves could contain some amounts of oil content. The turmeric leaf oil has less viscosity than as compared to gasoline. So it can undergo even better combustion than the gasoline, thus could be able to improve the performance.

### ii. Turmeric leaf biodiesel

#### a. Preparation of biodiesel

The vegetable oil when extracted from the resources contains fatty acids, water, sterols, phospholipids, odorants and impurities. If it is directly injected into the diesel engine, it may cause numerous severe problems. These may occur because of high viscosity, low volatility and poor cold low properties. These may lead to engine deposits, injector choking, piston ring sticking, etc. Thus, it becomes mandatory to make some chemical processes over the oil in order to make it suitable for the engine without any

modifications in existing parts. For this purpose, various chemical methods are used. The effective methods used for fulfilling the objective are:

- 1) Pyrolysis
- 2) Micro-emulsification
- 3) Dilution
- 4) Trans-esterification

### Trans-esterification Process

The trans-esterification process involves certain number of reactions and processes as shown in the figure above. The steps involved in the trans-esterification process are as follows:

- 1) **Mixing of alcohol and catalyst:** A specified amount of methanol is added with a measured quantity of NaOH, which acts as catalyst, into a flask.
- 2) **Reaction:** This mixture is then added into a closed reaction vessel and the respective vegetable oil is added and heated to 60-80°C. This reaction converts the fats into the esters. Sometimes, an extra amount of fuel can be added in order to ensure complete conversion of fats to esters.

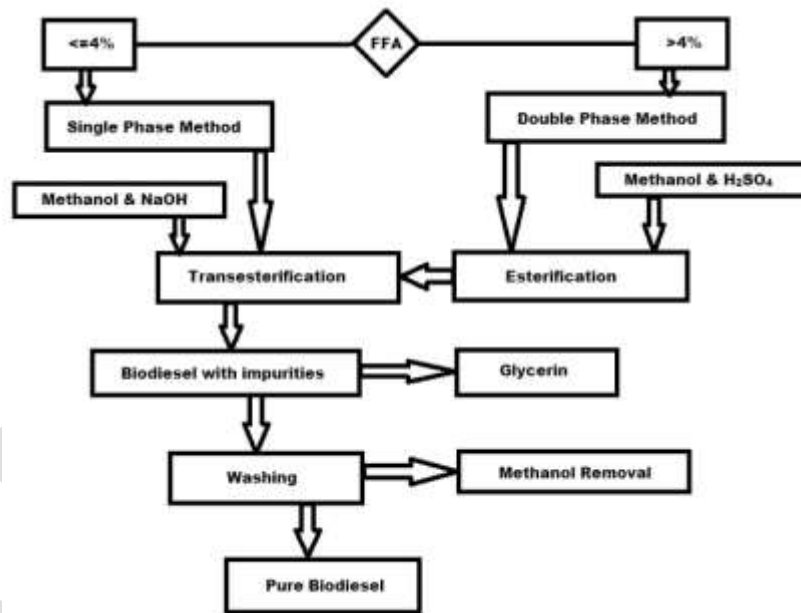


Fig 1: Trans-esterification process

- 3) **Separation of biodiesel and glycerin:** After the completion of reaction, two products exist: biodiesel and glycerin. The quantity of glycerin varies as per the kind and quantity of vegetable oil.
- 4) **Removal of alcohol:** The mixture of biodiesel and glycerin is heated up to 60°C, thus producing the steams, which separates the amount of glycerol from the mixture. The methanol is sufficiently dry in order to recirculate it back into the reaction.
- 5) **Glycerin neutralization:** The glycerin byproduct contains unwanted quantity of catalyst and soap and needs to be neutralized with an acid.
- 6) **Methyl ester wash:** This is the final phase which ensures the complete removal of unwanted contents from the biodiesel, so as to make it compatible with the diesel engine.

The single phase method is applicable only if the amount of free fatty acids (FFA) in vegetable oil is less than 4%. This involves a measured amount of alcohol as methanol and the catalyst NaOH and the mixture is heated and maintained at 65°C. In case of fatty acids more than 4%, double phase method is applicable. It involves mixture of H<sub>2</sub>SO<sub>4</sub> and methanol to be taken and added and supplied to esterification process first and then it is heated and maintained at 65°C. This is then passed onto and previous process is carried out.

#### b. Properties of turmeric leaf biodiesel:

The chemical properties of the biodiesel play very important role. The following section compares the various properties of turmeric leaf oil with diesel:

Table 2: Comparison of properties of turmeric leaf oil with diesel

Properties	Diesel	Turmeric leaf oil	Acceptable range
Chemical formula	C <sub>12</sub> H <sub>23</sub>	C <sub>21</sub> H <sub>20</sub> O <sub>6</sub>	-
Molecular weight	196.23	368.379	-
Density (m <sup>3</sup> /kg) a 20°C	842	925	800-950
Kinematic viscosity (mm <sup>2</sup> /s) at 40°C	2.5	7.82	1.9-8.0
Calorific value (kJ/kg)	44000	43672	-
Flash point (°C)	70	102	>130

It can be observed that the calorific value of turmeric leaf oil is comparable to that of diesel. Also its density is within the acceptable range as per the ASTM norms. The viscosity is the factor which signifies whether the engine parts needs to be modified or not. Since, it is also in the acceptable range, there is no such issue. This makes the turmeric leaf biodiesel to be experimentally fit without any modifications in parts of the engine.

#### SUMMARY

- As per the study concluded, it is feasible to work over the turmeric leaf biodiesel in a variable compression ratio engine.
- Though, the experimentation would show the results including relatively less performance as compared to diesel, it would definitely produce similar brake power with slightly higher fuel consumption.
- It is better to use the trans-esterified biodiesel with or without blending in the diesel engine as it would add an advantage of fuel flexibility without making changes in existing parts along with assurance for extended engine life.
- It should be noted that, the range of blending that should be considered during experimentation is 10-30%, as it can be seen from literature survey to obtain satisfactory results.
- The emissions using the biodiesel could be satisfactorily reduced; the CO, CO<sub>2</sub>, and HC reduce while the NO<sub>x</sub> emissions should increase because of higher oxygen content and higher exhaust gas temperature as compared to that with diesel.

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