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Investigating Catalyzed Transesterification for Castor Oil Ethyl Ester Production: A Promising Biodiesel Substitute

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Abstract: This study investigates the catalysed transesterification method for producing castor oil ethyl ester (COEE), a biodiesel substitute. The research looks at a number of variables that impact the reaction, including temperature, the ratio of alcohol to oil, the concentration of the catalyst, the amount of mixing, and the purity of the reactant. In the experimental setting, biodiesel is created in a lab and tested on a diesel engine. The outcomes show that the transesterification procedure successfully lowers castor oil's viscosity and raises the fuel's cetane number. According to engine testing, a 20% blend of COEE demonstrates promising performance with conventional diesel fuel-like energy consumption and thermal efficiency. The study emphasises COEE's potential as a superior biodiesel alternative with viability.
Keywords: Castor Oil Ethyl Ester, transesterification, alternative fuel, brake thermal efficiency, diesel engine

I. INTRODUCTION

The industrialization and rapid population growth in the world have raised the demand for energy. As a result, if current consumption continues at its current rate, the energy reserves currently available will soon run out. According to estimates from the Oil and Gas Journal (O&GJ), there were 1.27 trillion barrels of oil and 6.100 trillion cubic feet of natural gas in the world's oil reserves at the start of 2004**.** However, the present rate of oil consumption is roughly 85 million barrels per day, while the daily rate of natural gas consumption is 260 billion cubic feet. If the remaining time is estimated, the current oil reserves can only be used for another 40 years and the current natural gas reserves for another 64 years. Additionally, a rapid rise in pollutant emissions caused by the usage of petroleum fuels would have an impact on human health, leading to disorders of the respiratory, neurological, and skin systems, among other things. Therefore, the need for energy has increased, and environmental concerns have prompted research into finding an alternate fuel [1]. Fossil fuels, which can be obtained from plant origin such as ethanol or biodiesel, are being substituted for conventional fuels as a result of reserve shortage and rising fuel prices. In order to produce these fuels from renewable resources, this substitution necessitates increased research and development efforts. In other words we need manufacture of alkyl esters (bio diesel) from vegetable oils, which can be created utilizing several catalytic processes [2]. Basically we cannot use the raw vegetable oils in diesel engines without modifying the engine because it results very poor engine performance and also leads to damage the engine components [3].This reserve’s shortage is encouraging the Bio fuel discovery and research in all manners. If we look to the history of the Bio-diesel we found that all it started from the beginning of the 21st century when almost all vehicles was running on gasoline or diesel or natural gas. The development of biofuels as an alternative to mineral oil-based petrol and diesel was halted as a result of the oil industries' decision to invest in infrastructure to enable long-distance diffusion of easily exploitable but less expensive petroleum resources. However, following the 1970s oil crisis, biofuels gained impetus once more. However, as oil prices fell again, so did consumer interest in biofuels. Now days the interest use of bio-fuels for energy generation purposes is increased because they not only allow mitigation of greenhouse gases, but also provides mean of energy independence. It may also produce many other employment opportunities. In this regard, it is believed that biofuels, which are environmentally favorable, represent hope. These fuels are non-toxic, biodegradable, sulfur-free, and devoid of substances that cause cancer, such as benzene [4]. In this context, it is thought that environmentally friendly biofuels provide hope. These fuels are free of carcinogens like benzene, are non-toxic, biodegradable, and contain no sulphur [5]. A biodiesel fuel, according to the American Society for Testing and Materials (ASTM), is a mono-alkyl ester of long-chain fatty acids generated from renewable lipids, such as vegetable oil or animal fat. As an alternative to conventional petroleum-based diesel fuel, biodiesel emphasizes its recyclability and biological sources, whereas diesel refers to its use as a fuel for diesel engines. When utilized as an alternative fuel, biodiesel has various advantages [6]. There are numerous varieties of biofuels available.

The most promising biofuels are those that are naturally oxygenated, such as bio-ethanol, vegetable oils, and some derived bio diesels like methyl or ethyl esters. As a result, biodiesel, which is created by combining vegetable oil or animal fat with a pure alcohol like methanol or ethanol, serves as an alternative fuel for diesel engines. Additionally, a strong base catalyst like sodium or potassium hydroxide is needed for this reaction. After the reaction, methyl or ethyl esters, a new chemical product was created. These esters are commonly referred to as biodiesel. Fundamentally, biodiesels are more flammable and safer to handle or transport than petroleum because they have a higher flash point (about 150^0C). Additionally, biodiesels have high lubricating qualities that help lessen engine wear and tear while also extending engine life. In conclusion, biodiesels are superior than petroleum in many ways, especially in locations with high environmental concerns [7]. Although the supply of fossil fuels is running out more quickly than ever before and there is a greater need for energy for transportation and comfort, there is also a need to boost the production of biodiesel. The most widely used alternative to diesel fuel is bio-diesel, which is made from some renewable sources.

Alternative energy sources because they are biodegradable and non-toxic. As is well known, India has enormous potential for producing biodiesel from oil seeds that cannot be consumed. Although there are roughly 100 different types of oil seeds in India, only 10 to 12 of them have been harvested thus far. Mahua India (Mahua), Castor (RicinusCommunis), Jatrophacurcas (RatanJyot), Pongamia Pinnata (Karanja), and Melia Azadirachta (Neem) are among of the promising non-edible sources suitable for biodiesel production in India. The extraction of oil from tree-borne oil seeds yields biodiesel that is entirely dependent on the biological, chemical, and occasionally genetic characteristics of the plant. The oil seeds are described for their various tree-born varieties as well as their properties, potential, and chemical make-up. An excellent business opportunity can be created that can offer a significant contribution to the production of an eco-friendly transportation fuel that may be relatively clean to the environment and give farmers a sizable income if some developed processes are scaled up to the commercial levels [8]. A fuel known as biodiesel (BD) is created when an alcohol and a vegetable oil or animal fat undergo a reaction known as transesterification in the presence of a catalyst. Even though the existence of some substrates makes it more difficult to separate the mixture, understanding the complicated reaction kinetics makes it easier and necessitates a substantial amount of data.

They take a lot of time and money. It is also not usually practicable to record all reactants on a single profile. Researchers have looked at using flame ionization detectors (FID) or modified staining techniques in conjunction with thin layer chromatography (TLC) to analyze the material. In essence, there is no background information provided for the staining process, which is well suited for quantitative analysis. General concepts of online analysis response are addressed along with a few relevant calibrations that are also offered. Rapeseed oil to Biodiesel conversion yielded numerous experimental samples. Within 6 hours, the first response produced an 85–95% conversion. Following the elimination of glycerol and water, the second stage boosted the yield percentage by 97–98%. Following analysis, all mixture components were isolated and measured. Thin layer chromatography and gas chromatography were used to measure the relationship between the biodiesel contents, and the results showed values of 1.03 0.07 (TLC-staining) and 0.95 0.04 (TLC-FID), which demonstrates the applicability of TLC-methods [9]. Numerous research projects have been conducted in which important biodiesel known as waste fried oil methyl ester has also been tested for performance in four stroke single cylinder diesel engines fuelled with blends like WFOEE30, WFOEE50&E20. Various types of biodiesel have been tested in various blend ratios with diesel. Then, the outcomes were evaluated against regular diesel fuel. Compared to petroleum diesel fuel, WFOEE blends' fuel attributes have a higher flash point (1720C), which makes them less volatile and safer to carry. For all engine brake loads, WFOEE and ethanol blends' brake thermal efficiency fell short of petroleum diesel fuel. Due to their higher viscosity and lower calorific value, the WFOEE30&WFOEE50 blends' Brake Specific Energy Consumption (BSEC) is higher than that of standard diesel fuel. The analysis described above thus concluded that the diesel engine operated normally throughout testing while it was fueled with WFOEE30, WFOEE50, and E20 mixes. When compared to WFOEE30 and E20 blends, the WFOEE50 performed poorly. In the future, WFOEE30 and WFOEE50 blends made from leftover frying oil could replace traditional diesel fuel [10]. Other Biodiesels were tested as well, and the results of the tests revealed that Biodiesel has a slightly higher B.S.E.C. than diesel fuel for all engine brake loads at 100% load conditions. However, compared to diesel, using biodiesel lowered NO and smoke emissions. Additionally, biodiesel demonstrated a slower rate of heat release, a minute-long ignition delay, and some longer combustion times [11].

Castor Seeds are the main source of Bio-Diesel among Non-Edible Oils. Basically, the castor (Ricinus Communis) plant grows more quickly and is usually found in marginal or moderately saline soil. In all tropical areas of the planet, this land is extensively dispersed. To extract oil from its seeds, it has been grown commercially all throughout Pakistan and India's wastelands and coastal sand belts. This oil is a valuable medical resource and a cheap commodity. Scientists are working hard to create biodiesel out of oil derived from forests or less significant plants for economic reasons while facing a shortage of petroleum reserves. Therefore, castor and other non-edible oil-producing plants are thought to be ideal study candidates.

In order to explore the feasibility of converting castor oil into biodiesel, the work reported here examines the transesterification of castor oil, which was derived from castor seeds [12]. Numerous studies have been conducted, and the results suggest that triglycerides from vegetable oils or animal fats could be used as alternative diesel fuel. According to some documented literature, transesterification can be carried out on edible oils such as rapeseed, soy, canola, and sunflower using methanol and a catalyst of sodium or potassium hydroxide, however there are very few investigations on non-edible oils. It has occasionally been noted that the attributes of biodiesel are comparable to those of diesel and it complies with many nations' fuel requirements. Additionally, it was noted that biodiesel's combustion properties are comparable to or occasionally even superior to those of diesel, and that it produces power that is on par with diesels. The use of biodiesel in engines does, however, reduce engine emissions. The addition of various antioxidant inhibitors may help to slow down the oxidation process that occurs when biodiesel is stored. According to a paper on economic viability, biodiesels made from non-edible oils are less expensive than those made from edible oils. Consequently, this analysis concluded that biodiesel might be a better renewable alternative to diesel. [13]. The average increase in B.S.F.C. was found to be about 27.73% and 15.31%, respectively, while the brake specific energy consumption of diesel engines fueled with 50% and 100% blends of KOME increased by 12.44% and 8.91%, respectively, as compared to clean diesel fuel. The B50 and B100 KOME mixes of diesel fuel also shown an average increase in B.S.E.C. of 0.85%, 0.8%, and 1.1% with 10% EGR in compared to the same fuel without EGR [14]. A test has been conducted to see if jatropha methyl ester may be used as fuel in a compression ignition engine (C.I.) with combustion chamber turbulence induction. As is well known, insufficient air-biodiesel oil mixing results in insufficient fuel combustion. Therefore, to solve this issue, two holes known as internal jet pistons can be added to the piston crown to increase the turbulence inside the cylinder. Performance parameters showed that internal jet pistons had a higher thermal efficiency for braking than base engine pistons when using jatropha oil methyl ester. Lower emissions of carbon monoxide (CO), hydrocarbons (HCs), and smoke were among the many favorable properties of jatropha oil methyl ester operation with internal jet piston. However, as the load increased, the nitrogen oxides (NOx) emissions were higher with internal jet pistons compared to base engine pistons. [15].

A. Conventional Fuels On Indian Scenario

Even while emerging nations house 80% of the world's population, their net energy consumption accounts for just around 40% of global energy use. Improved energy consumption levels are also a result of developed countries' improved standards of living. Additionally, compared to a highly industrialized and developed country, the per capita energy consumption in poor countries is incredibly low. Currently, each person in the globe uses about 2.2 tons of coal worth of energy every year. However, in certain industrialized nations, per-person consumption is four to five times higher than the global average and nine times higher than the average in poor nations. According to a study, Americans use 32 times more energy than Indians do. Table 1.1 displays the primary energy consumption for a select number of industrialized and developing nations. Although coal accounts for 55% of all primary energy output in India, it dominates all other energy sources. The share of natural gas in primary energy production has risen from 10% in 1994 to 13% in 1999, whereas the share of fossil fuels in energy production has decreased from 20% to 17% over the same time period.

Table 1.1: Primary Energy Consumption By Fuel, 2003

In Million tones oil equivalent						
Country	Oil	Natural Gas	Coal	NuclearEnergy	Hydro-ElectricEnergy	TOTAL
U.S.A.	914.3	566.8	573.9	181.9	60.9	2297.8
Canada	96.4	78.7	31.0	16.8	68.6	291.4
France	94.2	39.4	12.4	99.8	14.8	260.6
Russia	124.7	365.2	111.3	34.0	35.6	670.8
U. K.	76.8	85.7	39.1	20.1	1.3	223.2
China	275.2	29.5	799.7	9.8	64.0	1178.3
India	113.3	27.1	185.3	4.1	15.6	345.3
Japan	248.7	68.9	112.25	52.2	22.8	504.8
Malaysia	23.9	25.6	3.2	-	1.7	54.4
Pakistan	17.0	19.0	2.7	0.4	5.6	44.8
Singapore	34.1	4.8	-	-	-	38.9
TOTAL	3636.6	2331.9	2578.4	598.8	595.4	9741.1

The majority of India's energy supply comes from conventional fuels. The world's 8.6% remaining coal reserves may endure for 235 years. Oil makes up 36% of the energy we use, while imports make up 70%. The demand for natural gas, which is predicted to increase by 200 mcmd, exceeds supply. Hydropower accounts for 15% of all electricity production, followed by thermal energy (77,940 MW), nuclear energy (2.4%), and wind energy (1,870 MW).

B. Final Energy Consumption

The total energy used is essentially the user's actual energy demand. It is the difference between the amount of primary energy used and the amount lost through transport, transmission, distribution, and refinement. Table 1.2 provides the actual final energy usage for the past and anticipated years.

Table 1.2: Demand For Commercial Energy For Final Consumption

Sources	Units	1994-95	2001-02	2006-07	2011-12
Electricity	Billion Units	289.36	480.08	712.67	1067.88
Coal	Million Tonnes	76.67	109.1	134.99	173.47
Lignite	Million Tonnes	4.85	11.69	16.02	19.07
Natural Gas	Million Cubic Meters	9880	15730	18291	20853
Oil Products	Million Tonnes	63.55	99.89	139.95	196.47

C. Bio-Diesel& Bio-Ethanol In India's Context

Only 1% of the world's biofuel production is produced in India. Only 380 million litres of ethanol fuel and 45 million litres of biodiesel fuel are included in this. It is important to note that while our nation produces 1% of the world's ethanol, it is the second-largest producer of sugarcane in the world. According to this statistic, 70–80% of the sugarcane grown in India is used to make sugar, and the remaining 20–30% is used to make other sweeteners like jaggery and khandsari. According to estimates, 42 kg of molasses and 85–100 kg of sugar can readily be generated from one tone of sugarcane. However, out of the entire amount of alcohol generated in India, 25% is utilized for industrial purposes, followed by 30-35 % for alcoholic beverages, and then 3-4% for other uses. Therefore, extra alcohol production can be used as fuel. India now imports a lot of the palm oil, olive oil, and other vegetable oils it needs to meet its domestic demand because it is not self-sufficient in producing edible oil. India cannot create biodiesel using its own vegetable oils made from rapeseed, mustard, or palm oil. In India, biodiesel is mostly made from the oils derived from non-edible seeds like Jatropha, Castor, and Pongamia; however, the cultivation of these plants and the practices surrounding them are not sufficiently supported by research. For instance, regardless of the soil conditions, intercropping is required for the cultivation of pongamia and jatropha. This international company focuses on seeds, fruiting, and optimum irrigation. Lower biodiesel output in India is partly a result of higher production costs and an excessive focus on feedstock. Additionally, because of the influence on forest protection, it is exceedingly difficult to obtain an acceptable amount of waste land **[**22**].**

D. Properties Of Bio-Diesel Fuels

There are many Properties by which a Bio-Diesel can be compared and evaluated with other fuels. A good fuel needs to have optimum value to achieve the tag of a sufficient Alternate Fuel.

1. Relative Density
2. Flash point
3. Fire point
4. Cloud Point.
5. Pour Point
6. Viscosity

II. OBJECTIVES

The main objective of this dissertation work is to prepare the biodiesel from Castor Oil, which is obtained by the seeds of the Castor plant by transesterification process and investigate the properties of Castor Oil Ethyl Ester (Biodiesel) and the performance parameters of a Single Cylinder Four Stroke Diesel Engine using Castor Oil biodiesel (COEE) blends and compares it with the Diesel blends. Castor Oil Ethyl Ester blends with diesel are COEE10, COEE20, COEE30, COEE50 and COEE 100 (Neat Bio-Diesel) fuelled in Four Stroke Single Cylinder Direct Injection Diesel Engine. The blends are COEE10 means (10% COEE and 90% Diesel), COEE20 (20% COEE and 80% Diesel), COEE30 means (30% COEE and 70% Diesel), COEE50 (50% COEE and 50% Diesel) and COEE (100% COEE Neat). The Castor Oil Ethyl Ester (COEE) blends are used in Direct Injection Single Cylinder Four Stroke Diesel Engine. Keeping this in view the objectives of this dissertation has been formulated as:

1) Analyze the performance parameters of diesel engine then compared with neat Diesel fuel and standard ED20 (20% Ethanol and 80% Diesel).
2) Basically, the ED 20 (20% Ethanol and 80% Diesel) blend is proved the best substitute fuel for the Neat Diesel fuel in previous research. So, I wanted to Figure out this how effective the Castor Oil Ethyl Ester blends are found over ED 20(20% Ethanol and 80% Diesel).
3) Find the suitability of these blends for Diesel Engine.
4) The following properties and performance parameters of COEE blends are to be investigated:

A. Properties

- Relative Density
- Fire point
- Pour Point
- Flash point.
- Cloud Point.
- Viscosity

B. Performance Parameters

1. Brake Specific Fuel Consumption (BSFC).
2. Brake Thermal Efficiency (BTE).
3. Brake Specific Energy Consumption (BSEC).
4. Heat Balance

III. RESEARCH METHODOLOGY

A. Materials Required

There are many materials which are required to produce the Castor Oil Ethyl Ester (COEE) in which the Vegetable Oil (Castor Seed Oil), Alcohol, NaOH or KOH as catalyst are required. Castor Seed Oil (99.9% Pure), Ethanol (99.99% Pure) laboratory grade and Potassium hydroxide (85%), were all collected from B Chemicals Supplier, Vijay nagar, Indore. A brief description about the materials is given below:

B. Vegitable Oil

Oil should have an FFA concentration of less than 1%. It was discovered that the better the biodiesel conversions, the less FFA there is in the oil. Higher FFA oil can also be used, but the amount of potassium hydroxide (KOH) or sodium hydroxide (NAOH) catalyst employed will determine the biodiesel conversions.

C. Alcohol

Methanol, ethanol, propanol, butanol, and amyl alcohol are among the substances used as alcohols. The most often utilized alcohols are methanol (CH3OH) and ethanol (C2H5OH). The closest thing to absolute that may be used is methanol or ethanol. Similar to oil, alcohol's water content has an impact on conversion to an extent that keeps glycerol from separating from the reaction mixture.

D. Catalyst

The initiator Transesterification can be carried out using either sodium hydroxide (NAOH) or potassium hydroxide (KOH). Alko-oxides can also be employed as catalysts, but the cost is too high. The catalyst must contain 85% potassium hydroxide (KOH) to produce the best results. The water content in the best grades of potassium hydroxide (KOH) ranges from 14% to 15% and cannot be eliminated. Because carbonate is a poor catalyst and could make the finished ester cloudy, it should be low in carbonate.

E. Methods

The different production conditions for methyl ester are mainly brought on by chemical processes. Higher ester yields and a quicker reaction time would come from raising the temperature during transesterification to up to 70°C. It is necessary to prevent ethanol from evaporating at these temperatures. There is a need for more pressure and vigorous agitation. At even lower temperatures, other authors noted a similar pattern of conduct. For the manufacture of methyl esters, somewhat more catalyst is advised because, otherwise, the ester yields would be too low. Due to better ethanol solubility in the oil, the overall kinetics of ethyl ester production are equivalent to or even slightly better than those of methyl ester production. Therefore, reaction duration, catalyst quantity, and reaction temperature are the three variables that have the greatest effects on the rate of the reaction and must be optimized for production.

A significant barrier to the manufacturing of ethyl ester is phase separation. The fundamental cause of this is because ethanol dissolves far more easily in the ethyl ester phase than methanol does. Another significant factor is the discovery that saponification during ethanololysis is more crucial than during methanolololysis. Generally speaking, adjustments to traditional biodiesel processes may be necessary for phase separation of glycerol. A neutralization process involving the addition of inorganic acids like HCl would be one potential method for the separation of water-soluble compounds. Other acids have been observed to generate emulsions that can only be separated by adding a 20% NaCl solution (acetic acid, H2SO4, and H3PO4, for example). Transesterification is the process that is most frequently used to produce biodiesel. Transesterification, also known as alcoholysis, is the process wherein one alcohol is used to replace another alcohol in an ester. It resembles hydrolysis exactly. Methanol, ethanol, propanol, butanol, and amyl alcohol are the principal acceptable alcohols. The most often used substances are ethanol and methanol.
Triglycerides (Vegetable Oils) have frequently been reduced in viscosity using this method. The generic equation represents the transesterification reaction:

RCOOR’	+	R”OH	=	RCOOR”	+	R’OH
(Triglyceride)		(Alcohol)		[Easter(Bio-diesel)]		(glycerin)

Where:
Represents any alkyl group (C_2H_5, C17H35oranyCnH2n$_{-1}$type alkyl radicals).

Vegetable oil + Methanol\Ethanol + Catalyst $\Longrightarrow$ Methyl\Ethyl Ester + glycerine

Figure3.1: Transesterification Process

If methanol is used in the above reaction it is termedas Methanolysis. The Reaction of Triglyceride with Methan Olis Represented by the general equation given below:

CH_2OOR_1					CH_2OH
$CHOOR_2$	+	$3CH_3OH$	$\longrightarrow$ $3CH_3OOR_x$	+	
$CHOHCH_2OOR_3$					CH_2OH
Triglycerides		Methanol	Biodiesel (Methyl Ester)		Glycerol

If Ethanol is used in the above reaction it is termed as Ethanol sis. The reaction of Triglyceride with Ethanol is represented by the same equation given below:

CH_2OOR_1					CH_2OH
$CHOOR_2$	+	$3C_2H_5OH$	$\longrightarrow$ $3C_2H_5OOR_x$	+	
$CHOHCH_2OOR_3$					CH_2OH
Triglycerides		Ethanol	(Ethyl Ester Biodiesel)		Glycerol

Triglycerides are easily trans-esterified when an alkaline catalyst is present, at atmospheric pressure, between 60 and 70 °C, and when there is an excess of methanol. Only a 5:1 molar ratio of methanol to triglycerides is necessary to produce 95–98% of the desired amount of methyl esters since the equilibrium constant favours the synthesis of methyl esters. It may be expected that glycerol would be crucial to obtaining conversions close to 100% in such a system. At the conclusion of the reaction, the mixture is allowed to settle.

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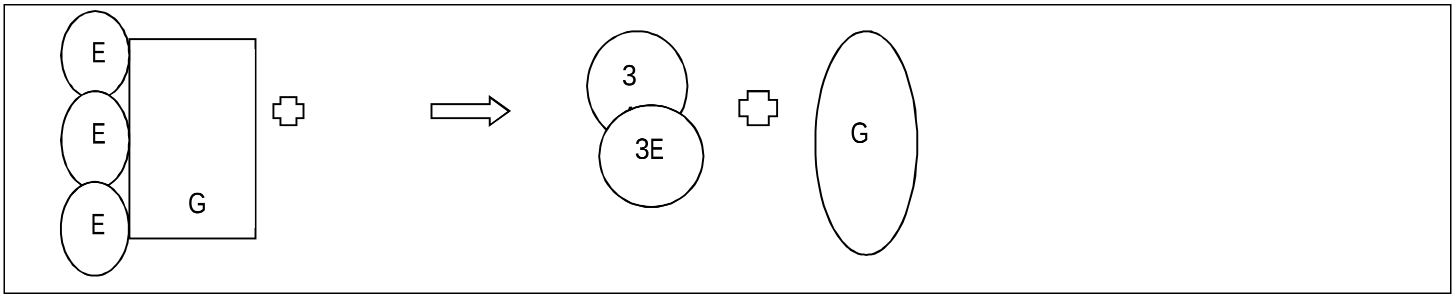
The upper portion of the methyl ester layer is treated after being water washed to remove entrained glycerol while the lower portion of the glycerol layer is pulled off. Distillation is used to recover the extra methanol, which is then transferred to a Rectifying column for recycling and purification. When the starting oil is of excellent quality, the transesterification functions effectively. When an oil's FFA level is above 1%, problems can arise since soaps for motion encourage emulsification during water washing, and if the FFA percentage is beyond 2%, the process is no longer feasible. Alko- and hydroxides were the catalysts said to be effective at room temperature.



Figurere3.2: Graphical Representation of Trans-Esterification process

Where

E: Ester group E: Ester group E: Ester group

F. Variables Affecting Transesterification Reaction

1. Temperature of oil.	3. Alcohol to oil ratio.	5. Intensity of mixing.
2. Temperature of reaction.	4. Type of catalyst and its concentration.	6. Purity of reactants. 7. Stirring rate.

IV. EXPERIMENTAL SETUP AND CALCULATION

The Bio-Diesel is produced and filtered in the Laboratory and then tested in a Single Cylinder Four Stroke Direct Injection Diesel Engine in different ratio mixed with pure Diesel. All the setup details and methodology has been described in this chapter.

A. Preparation Of Biodiesel From Castor Oil

1) Production Of Bio-Diesel

As we know there are many processes by which oil can be converted into Bio-Diesel. Basically there are more than 50 methods which are in research and development as well as recently being used by developed country.

Some of the processes are listed below:

a) By Catalysed Transesterification Process with direct mixing of Alcohol.
b) By Non-Catalysed Supercritical Alcohol Transesterification process.
c) By conversion of oil to fatty acids, then to Alkyl Ester with Acid Catalysis.
d) By Transesterification use of Solid supported Acidic Salt Catalyst.
e) By Biological conversion using Alga and Bacteria (Stilling research).

In above given methods, I have used the Catalysed Transesterification process with direct mixing of Alcohol with the Castor Oil to produce the Bio-Dieselfromoil.

2) Transeterification Process

Transesterification is the most popular method of producing biodiesel, in which the reaction of a free fatty acid takes place with the Alcohol in the presence of Catalyst (Sodium Hydroxide or Potassium Hydroxide). After the reaction with applying of heat and uniform stirring as a product the Triglyceride and Ester (Bio Diesel) formed. After successfully completion of the reaction the products are left for time to settle down and both the product can be separated by flask with tap. The process is described by equation below while using Ethanol as Alcohol.

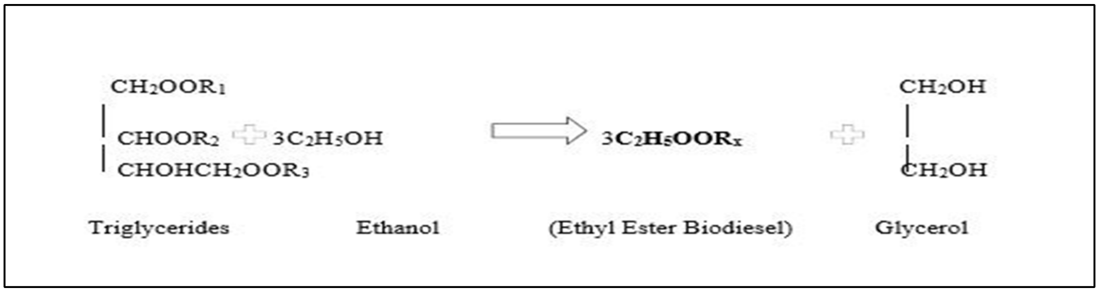


Figure4.1: Transesterification Process

The viscosity of the vegetable oil was altered throughout the transesterification process. The product has low viscosity, similar to fossil fuels, because the high viscosity component, glycerol, has been eliminated. The created biodiesel can be mixed completely with mineral diesel in any amount. After transesterification, the biodiesel's flash point is reduced and its cetane number is raised. The presence of moisture and free fatty acids (FFA), reaction time, reaction temperature, catalyst, and the molar ratio of alcohol and oil are all factors that affect the yield of biodiesel during the transesterification process. By transesterifying castor oil with either ethanol or methanol as the transesterification agent, biodiesel can be produced. Methanol transesterifies more quickly than ethanol during the biodiesel extraction process from castor oil when catalysts are present. The reaction time determines the highest production of esters, which is 1 hour with methanol and 5 hours with ethanol. Even though Methanol sis and Ethanolysis can produce equal yields of Fatty Acid Esters, the reaction times needed to get there are considerably different, with Methanolysis being much faster.

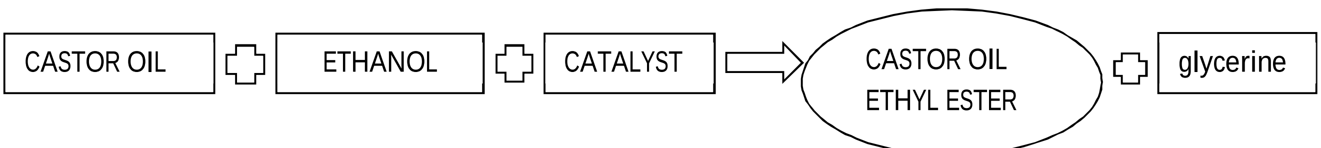


Figure4.2: Transesterification Process of Castor Oil

In the preparation of Castor Oil Ethyl Ester (Bio Diesel), five distinct stages will be involved, which are listed below:

a) Heating of oil.
b) Preparation of alkaline mixture.
c) Adding of Alcohol-Catalyst mixture to oil and stirring the mixture.
d) Settling of separation of glycerol.
e) Washing of ethyl ester with water.

B. Experimental Setup

To check the various parameters of the Ethyl Ester it is necessary to have devices and machines by which properties of the Bio-Diesel can be tested hence the description of the setup is dictated below:

1) Single Cylinder Four Stroke Diesel Engine

The Castor Oil ethyl Ester (COEE) had to be tested in an engine for various parameters. The engine was Single Cylinder Four Stroke Direct Injection Diesel Engine which is installed at our Fig.institution.

Figure5.5: Single Cylinder Four Stroke Diesel (CI) Engine Experimental Setup

C. Test Parameters

The most important part of this dissertation is to check the performance parameters of the Biodiesel which are prepared in different proportion. These mixtures are used to find different parameters under different load and in different condition. The blends are prepared COEE 10, COEE 20, COEE 30, COEE 50 and COEE 100 and Finally Neat Diesel and E20 tested for its results like fuel consumption, temperature etc. corresponding loads to be entered manually. The fuel consumption by the diesel engine is taken three times and finds the mean of fuel consumption and all other Parameters in per time. Each reading of diesel and blends has taken after the 15 minutes warm-up and when Engine Stabilized.

The Parameters which are tested to determine the engine performance are:

1. Load	4. Gas Outlet Temperature from Calorimeter.
2. Fuel Consumption Rate.	5. Temperature of Water Inlet to Calorimeter.
3. Gas Inlet Temperature to Calorimeter.	6. Temperature of Water Outlet from Calorimeter.

ENGINE PERFORMANCE PARAMETERS WHICH ACTUALLY TESTED

1. Brake Power.	3. Brake Specific Energy Consumption.
2. Brake Specific Fuel Consumption.	4. Thermal Efficiency & Heat Balance.

V. RESULT & DISCUSSION

The Transesterification Process is most commonly method used for direct conversion of Triglyceride lipids in Alkyl Ester. The main purpose of the transesterification of Castor Oil Ethyl Ester was to reduce the viscosity of the Castor Oil as it is most viscous non-edible oil and to increase the cetane number of the fuel. Transesterification reactions can be catalyzed by acids, alkalis or enzymes but alkalize specially Potassium Hydroxide broadly used. The Physical properties of Neat Diesel, Ethanol-Diesel blend (Ethanol 20%-Diesel80%) ED 20 and COEE after transesterification are shown in table below.

The specific gravity of Diesel, ED20andCOEEare obtained 0.84. 0.83 and 0.93 respectively. The COEE has high flash point 135^{o}C which is higher in comparison to conventional Diesel fuel (51^{o}C) at NTP, which makes it less volatile and safer to transport and handle than Petroleum fuels.

The Viscosity also found 3.2,15.6 and 2.5mm^{2}/s for Diesel, COEE and ED20 respectively. On engine testing for their performance parameters, it is found that the Castor Oil bio-Diesel 20% (COEE20) found the optimum blend to be used as the alternate fuel for the diesel and Brake Specific Energy Consumption (BSEC) is found almost same as Diesel fuel, which is only 3% to 8% higher than neat Diesel fuel.

Also the Brake Thermal Efficiency of COEE 20 found very near to the conventional Diesel fuel and sometimes better than Ethanol-Diesel 20% (ED20) blends. COEE 20 showed 10% to 5% more Break Specific Fuel Consumption than Diesel fuel as load increased but 2-5%lessB.S.F.C.compared to ED20 in same load condition. As the blends were increased (from 10% to 100%) for the same load condition the Break Specific Fuel Consumptions slightly increased but for the COEE20, it become optimum. When the Neat COEE is used in CI engine the B.S.F.C.is around 20-24% more than the Diesel fuel but compared to the ED20 fuel the fuel consumption was only1to 5% more.

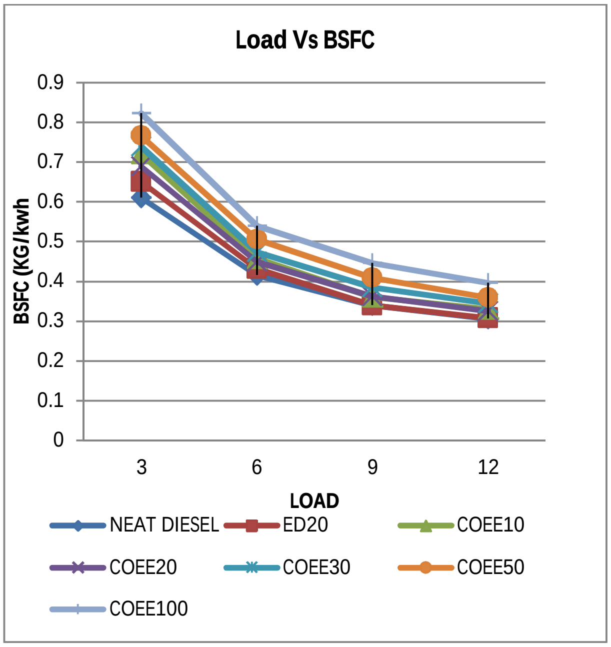
The brake thermal efficiency of biodiesel (COEE) is decreased slightly than that of diesel at same load condition when the blends are used of 20%. The Brake Power of biodiesel is approximately equal to diesel, while the Brake Specific Fuel Consumption was slightly increased as the loads were increased than that of Diesel. The that Brake Thermal Efficiency of COEE 20 is lowered by only 4-7% in different load condition while COEE 20 showed the Brake Thermal Efficiency lesser by only 1-3% which is almost same as ED 20fuel.

In brief the results found satisfactory for Castor Oil Ethyl Ester blends to be used as a Bio-Diesel like ED20, because the 20% blend of the COEE with Diesel, found of the same performance; but even better in high load conditions. It has been proved in their search that the Ethanol and Diesel blends are better alternate to Neat Diesel but according to this performance test also indicates that the COEE and Diesel Blends also can be the better option.

India produces maximum Castor seed in the world. If it will utilize in Bio-Diesel production, the supply of the Diesel can be reduce by10-15%

According to the performance results obtained by the Diesel Engine test kit graphs have been plotted to show the important parameters in brief and effectively, which are attached below:

A. Load Vs Brake Specific Fuel Consumption Graph For Fuels

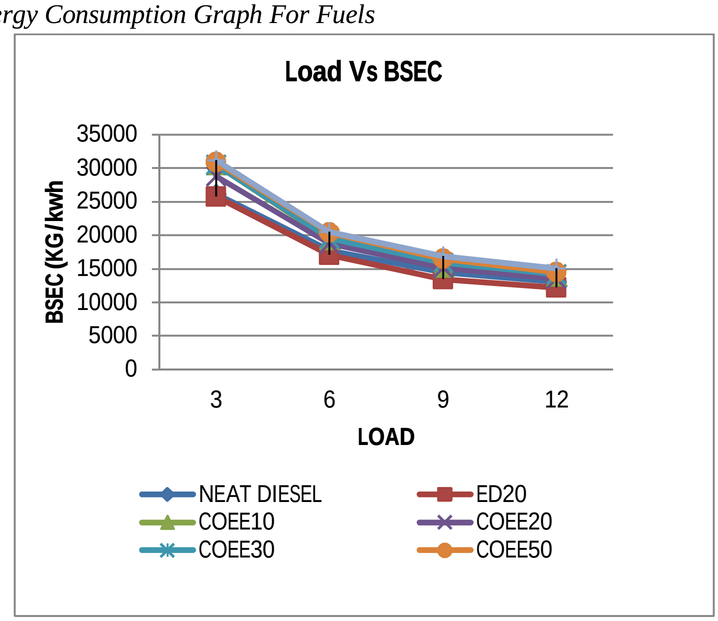


The first graph has been draw between load and Brake Specific Fuel Consumption. B.S.F.C. is an important parameter to check the performance of the fuel. As we can see from the above graph the B.S.F.C. decreases as the load increases. It means all the fuels give higher performance at higher load condition. Diesel indicates the minimum B.S.F.C. for lower loads and become equal to the ED20 for higher load condition.

- *Performance Of Costor Oil Ethyl Ester 20*

The COEE10 and COEE20 show the lower B.S.F.C compared to all other Bio-Diesel. The neat biodiesel leads to the maximum B.S.F.C. in all load condition. The COEE 20 analyzed as the optimum performer in Bio-Diesel blends used in Test Kit. The COEE100 blend consumes 22-25% more B.S.F.C. than neat Diesel while COEE20 only 5-10% more. If compared with ED20 it is only 5.33% more. Hence according to the B.S.F.C. it analyzed that COEE20 indicates the same performance as neat Diesel and ED20 in high load condition.

B. Load Vs Brake Specific Energy Consumption Graph For Fuels

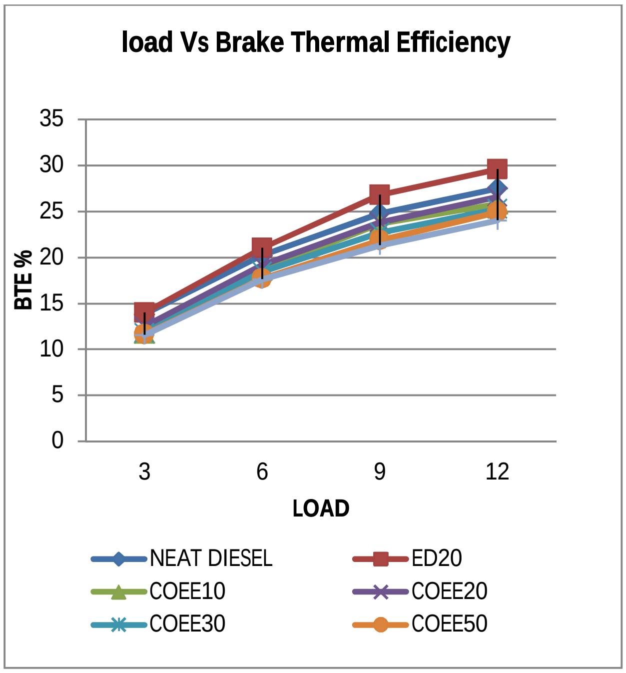


Another graph has been drafted between Brake specific Energy Consumption and Load. It has been analyzed that Brake Specific Energy Consumption is higher for the low load condition. As the load increase in the test kit the B.S.E.C. reduces. It indicates that the performance as well as the efficiency improves with the high load condition.

- *Performance Of Costor Oil Ethyl Ester 20*

In the graph ED20 indicates the lowest B.S.E.C in all fuels (Except Diesel at load of 3kg & 6kg) .B.S.E.C. of neat Bio-Diesel is 13-15% more than the neat Diesel while COEE20 Consumes 3-6% more B.S.E.C. than neat Diesel in different load condition. The B.S.E.C. of COEE50 and COEE100 is same. The B.S.E.C. of COEE 20 becomes closure to Diesel which indicates 7-10% more B.S.E.C. compared to ED20. In short the COEE20 possesses better alternative quality than other blends.

C. *Load Vs Brake Thermal Efficiency Graph For Fuels*



An important graph has also been plotted between Load and Brake thermal Efficiency. This graph shows the most important parameter of the fuels. As we can see, the ED20 shows the highest efficiency after in all fuels.

- *Performance Of Costor Oil Ethyl Ester 20*

It has been analyzed that Brake Thermal Efficiency of COEE20 is lowered by 4-12% in different load condition compared to neat Diesel while it showed the Brake Thermal Efficiency lesser by 11-17% in different load condition compared to ED20. The brake thermal efficiency of biodiesel (COEE) is decreased slightly than that of diesel at same load condition when the blends are used of 20%. The COEE100 indicates the lowest B.T.E. compared to all fuels used in test kit. The COEE100 has 14-19% lower efficiency than neat Diesel while indicates 21-23% lower efficiency thanED20. In Short COEE20 blend meets the expectation to be used as a Bio-Fuel.

VI. CONCLUSION

The process of transesterification is a most efficient method to transform the Triglyceride into ester. The specific gravity and flash point of COEE are high in comparison to Diesel fuel. It has also been concluded that the use of Biodiesel (COEE) blends slightly increases the brake specific fuel consumption (BSFC) in comparison to Diesel fuel at the same load condition. The Brake Thermal Efficiency of biodiesel fuel found close to Diesel fuel, when the blends were 20%. When the neat COEE is used in Diesel engine, COEE 20 and COEE 10 found more optimum fuel as an alternate fuel. If a single fuel to be selected for alternate fuel I shall choose the COEE 20 in place of COEE 10 as it reduces the Brake Specific fuel Consumption of Diesel fuel. In brief, it has been concluded that Bio-Fuel (COEE) is suitable alternative for Diesel engine.

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