Comparative Experimental Investigation of Thumba and Argemone oil Based Dual Fuel Blend in Diesel Engine for its Performance and Emission Characteristics

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AUTOMOBILE ENGINEERING

By

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CERTIFICATE

I hereby certify that the work being presented in the dissertation entitled "**Comparative Experimental Investigation of Thumba and Argemone Oil Based Dual Fuel Blend in Diesel Engine for its Performance and Emission Characteristics**" in partial fulfilment of the requirement of the award of the Degree of master of technology and submitted to the Department of Mechanical Engineering of Lovely Professional University, Phagwara, is an authentic record of my own work carried out under the supervision of ***Mr. Sumit Kanchan, Assistant Professor*** Department of Mechanical Engineering, Lovely Professional University. The matter embodied in this dissertation has not been submitted in part or full to any other University or Institute for the award of any degree.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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The external viva-voce examination of the student was held on successfully ___________

Signature of Examiner

DECLARATION

I, Shahid Qayoom (11616962), hereby declare that this thesis report entitled "**Comparative Experimental Investigation of Thumba and Argemone Oil Based Dual Fuel Blend in Diesel Engine for its Performance and Emission Characteristics**" submitted in the partial fulfilment of the requirements for the award of degree of Master of Technology in Automobile Engineering in the school of Mechanical Engineering, Lovely Professional University, Phagwara, is my own work. This matter embodied in this report has not been submitted in part or full to any other university or institute for the award of any degree.

Date: Shahid Qayoom

Place:

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TERMINOLOGY

BTE	Brake Thermal Efficiency	**VCR**	Variable Compression Ratio
BSFC	Brake Specific Fuel Consumption	**CR**	Compression Ratio
BSEC	Brake Specific Energy Consumption	**PPME**	Pongamia pinnata Methyl Ester
BP	Brake Power	**MEE**	Mustard Methyl Ester
HC	Hydrocarbon	**DI**	Direct Injection
CO	Carbon Monoxide	**TB**	Thumba Biodiesel
CO_2	Carbon Dioxide	**AB**	Argemone Biodiesel
NO_x	Oxides of Nitrogen	**CB**	Coconut Biodiesel
PPM	Parts Per Million	**B10**	Biodiesel 10%. Diesel 90%
EGT	Exhaust GasTemperature	**B20**	Biodiesel 20%, Diesel 80%
KOH	Potassium Hydroxide	**B30**	Biodiesel 30%, Diesel 70%
NAOH	Sodium Hydroxide	**B40**	Biodiesel 40%, Diesel 60%
RPM	Revolutions Per Minute	**B50**	Biodiesel 50%, Diesel 50%
CA	Crank Angle	**J**	Joule
CC	Cubic Centimeter	**AB10**	B10
CN	Cetane Number	**AB20**	B20
KG	Kilogram	**DPJ**	Diesel, Pongamia pinnata, Jatropha
^0C	Degree Celsius	**DPJ10**	B10
FFA	Free Fatty Acid	**DPJ20**	B20
TME	Thumba Methyl Ester	**TB10**	B10
TB20	B20	**JB**	Jatropha Biodiesel
JB10	B10	**JB20**	B20
KW	Kilo Watt	**D0JB50PB50**	Diesel 0%, Jatropha 50%, Palm 50%
D20JB40PB40	Diesel 20%, Jatropha 40%, Palm 40%	**B100**	0% Diesel, 100% Biodiesel
B0	0% Biodiesel	**AMME**	Argemone Mexicana Methyl Ester
TME	Thumba Methyl Ester	**FAMEs**	Fatty Acid Methyl Esters

ABSTRACT

Large amount of emission levels like carbon monoxide, NOx and Particulate matter from diesel engine results in environment issues and health problem. Also, mixing of soot in lubricating oil can result in increased wear and lubricant breakdown. Therefore, it is necessary to develop a viable fuel blend which can decrease the emission levels from diesel engine and which could be easily obtained from many available resources like vegetables rather than conventional fossils fuels.

This is an experimental approach made to develop a dual fuel blend from non-edible seeds like Argemone and Thumba oil running on diesel engine to evaluate for its performance and emission characteristics. This exertion aims to compare the various performance parameters like brake thermal, Mechanical and charge efficiency, Net heat release and Pressure-theta distribution for an engine running on Argemone, Thumba and Diesel dual fuel blend with that of engine running on diesel as a fuel. Attempts has been made to analyze and compare the emission characteristics of fuel blend (Argemone + Thumba + Diesel) with diesel based engine for CO, CO2, NOx and Particulate matter.

The tests were conducted on a BSIII commercial, single cylinders, four strokes, water-cooled direct injection, In-line overhead valve diesel engine. The operating conditions and test procedure were set as per the Idling and cruising conditions of a vehicle. The engine was made to run on diesel fuel at 1000, 1100, 1200, 1300, 1400 and 1500 rpm with 2kg and 2.5kg load respectively. The fuel consumption was then measured along with the Performance and Emission characteristics and the values were noted. The engine was then flushed out and the dual fuel blend was made to run at same operating conditions and test procedure. The comparative analysis is yet to be done and results has to be derived.

CHAPTER 1:

1.1 Introduction

Conventional fossil fuels are reducing with the respect of time and it has been estimated that these fuels will vanish in next few years. Apart from this, as emission level is increasing day by day due to these conventional fuels, it has become a dire need to develop some new alternative fuels to these non-renewable fossil fuels. From the economic and environmental point of view, biofuels are being considered as better alternative fuels to replace all non-renewable conventional fuels. For all alternative biofuels to be effective, it is important that they should be easy to renew and their availability should be higher and also should be environmental friendly.

Among the alternative fuels, vegetable fuels like Karanja oil, cotton seed oil, neem oil, Jatropha oil, palm oil, soybean oil etc. are being considered as the best promising alternatives relative to non- renewable fossil fuels. Even after developing these alternative fuels, there are some obstacles in making these fuels practically usable because of their limitations to high viscosity nature and less vaporization. Mostly research processes are going on to develop alternative fuels from vegetable oil because of having higher cetane number, high heat energy, stoichiometric air/fuel ratio nearer to diesel fuel. Vegetable oils as alternative fuels displays better non-toxic, depletion in pollution level properties. Mainly dangerous pollutant emissions from automobiles like particulate matter, hydrocarbon, CO etc. are reduced to a large extent. It has been found that vegetable oils have high oxygen content hence produces higher heating values. The main obstacles in using these vegetable alternative oils for long term periods are higher engine deposition, sticking of rings, clogging of injectors, increase in pour point of lubrication oil means higher viscosity. Therefore, the main important parameter to make these vegetable oils better alternative oils is to reduce their level of viscosity. Many researchers have developed many methods or techniques to reduce this problem like blending of various oils, heating of oil before delivered to engine combustion chamber, transesterification and pyrolysis. Mostly researchers prefer to mix these oils with diesel to prepare environmental friendly and high efficient biodiesels. Nowadays, there are many countries which are highly dependent on import or petroleum resources. Hence, for those countries, investing on obtaining alternative fuels from many available resources like vegetables etc. becomes very important for their development.

Biodiesel is being considered as the best alternative fuel by USA and at present lot of investment is being sanctioned by its government to develop these economic and environmental friendly zero emission fuels. Different countries have different resources for extraction of biodiesels like in Europe, rapeseed and sunflower oils are used and in US, soya bean oil is mostly used. Palm oil as raw material for biodiesel is used in Thailand. From previous literatures, it has been found that B20 biodiesel blend shows impressive performance while used in existing diesel engines without any modifications.

1.2 Historical background of Vegetable oils

The development of considering alternative fuels was at the top from the invention of diesel engine by Rudolf diesel in 1885 onwards. In 1912, He mentioned that in due course of time, vegetable oils will become a main source of fuel to propel vehicles and other machinery. He himself developed the diesel engine which was first tested on using peanut oil. On 18^{th} August 1893, Rudolf diesel make it possible to run a model developed by him using biodiesel. Hence, as a remembrance of this achievement, 10^{TH} August is being declared as "International Biodiesel Day". During 1920s and 1930s, many countries started focus over usage of vegetable oils for internal combustion engines. For the first time in 1937 by university of Brussels (Belgium), a patent was issued to transform vegetable oils in fuels by means of Alcoholysis or generally named as transesterification in which methanol or ethanol can be used to remove fatty acids from raw vegetable oils results in reduction in viscosity. After the eruption of Gulf crisis in 1973, which results in large number of researches related to vegetable oils. As the usage of vegetable oils alone becomes insignificant due to many problems like low volatility, high viscosity.

1.3 Advantages of Biodiesel

Many Researchers suggested that following are the main advantages to use vegetable oils by mixing with diesel fuel:

- Biodiesel does not consist any toxic component.
- It consists higher oxygen concentration which in turn results in better combustion and better bio-degradation process.
- Enhances improvement in engine life because of having higher lubricating properties.

- The handling, transporting risks in case of biodiesel are lower because of having higher flash points.
- Economically, biodiesel is considered as most preferred oil because it can be extracted even from used waste oils.
- The unique known important feature for biodiesel is that it can be renewed again and again other than petroleum.
- Biodiesel production can play a very important role in development of rural areas because of its easy availability and conversion of waste lands for cultivation purposes.

Along with above advantages of biodiesels, researchers also mentioned some disadvantages as well:

- Viscosity is higher.
- The viscosity increases further in low temperature conditions, which in turn leads to blocking of filter cavities.
- Due to low oxidation stability, ageing of biodiesels takes place rapidly due to which formation of deposits and corrosion occurs within the injection system.

1.4 Methods of production of Biodiesel

In order to remove the above discussed disadvantages like higher viscosity and low volatility, following methods are developed:

- Preheating
- Blending
- Pyrolysis (Thermal cracking)
- Transesterification (Alcoholysis)

1.4.1 Preheating

Preheating the raw vegetable oils before allowing to inject into the combustion chamber reduces its viscosity to a large extent. Preheating of vegetable oil at 80-100^{o}C reduces the viscosity of vegetable oil nearer to viscosity of diesel. Preheating further enhances the fuel-air mixture within engine by improving spraying characteristics. As a result, complete combustion can take place which reduces emissions effectively. Hence all the above discussed parameters indicates that preheating could play a vital role in production of biodiesels from vegetable oils.

1.4.2 Blending

Concentration of vegetable oils below 10% can be used to operate the engine without any higher modifications in engine. There are generally some limitations to use vegetable oil with diesel which can be used in long run conditions like 20% or 30% of vegetable oil. But as the concentration of vegetable oil increases, many problems have been found by many researchers like carbon deposition, resistance to flow, gum formation. These are the reasons to avoid usage of direct vegetable oil in both direct or indirect injection engines.

1.4.3 Pyrolysis (Thermal cracking)

Pyrolysis is being referred as the transformation of one substance into another under the action of heat along with a catalyst. Mostly, this process used to carry out since 100 years back in those regions where there are lack of petroleum resources.

1.4.4 Transesterification (Alcoholysis)

Transesterification is a method which is mostly used for removing fatty acids or glycerol from vegetable oils by sharing the Alkoxy group of an ester compound with alcohol along with a catalyst (acid or base) to vary the reaction time. In a transesterification process of a vegetable oil, triglycerides (fat/oil) reacts with three molecules of alcohol (ethanol or methanol) to form esters (Bio-diesel) and glycerol. Methanolysis and Ethanolysis in which Methanol and Ethanol are generally used as catalysts in Alcoholysis process. Among above two catalysts, generally methanol is being consumed because of its abundant availability and cheap in cost.

1.4 Biodiesel feedstock collection

There are variety of vegetable oils that are being selected as main sources for production of biodiesels as:

- Edible oil sources like soybean oil, mustard oil, palm oil, rapeseed oil, sunflower oil, etc.

- Non-edible oil feedstocks like, Castor, Jatropha, Mahua, Thumba, Argemone, Pongamia etc.
- Waste used cooking oil.
- Animal fats and Algae produced using waste raw material like sewage etc.

Before biodiesel production process, proper selection of biodiesel sources is being considered as very important parameter considering low cost of biodiesel production and less food crisis competition. In India, mostly non-edible oil like Jatropha oil is used for biodiesel production because of its high yield productivity per hectare of land.

1.5 Properties of biodiesels

Following are some important properties for biodiesels compared to pure diesel categorized as:

- Higher Cetane number
- Higher viscosity
- Higher flash point
- Higher density
- Higher lubricity
- Higher acid value

CHAPTER 2:

2.1 Scope of the study

Biodiesel is being considered as the popular and most preferred economic and environmental friendly alternative fuel because it belongs to renewable sources like vegetable oils and also consists higher oxygen content results in complete combustion and reduction in emissions. Since, the demand for edible oils in India is very high due to which it is very difficult to replace their use for production of biodiesels. Hence working on biodiesel extraction from various non-edible oils like Argemone Mexicana and Thumba oil could be feasible and can reduce the food crisis as well. Following are the main considerations which clearly concludes that the research work on biodiesel from Argemone Mexicana and Thumba could give impressive results:

- The net heat release rate for dual biodiesel blends was found lower than pure diesel. Therefore, further investigation can be carried out to increase the net heat release rate.
- It was found that by-products like fatty acids or glycerol are produced after the transesterification process. Hence a lot of research work can be done to use these by-products for various industrial purposes which can results in economical biodiesel extraction.
- As many researchers concluded that 1-6% of NO_X emission increased by using dual biodiesel blends, hence more research study can be done to reduce their NO_X level by changing various engine hardware components.
- It was concluded that the transesterification process of vegetable oils increases the water hazards level. Hence a lot of research area is available where number of techniques can be developed which can signify the importance of waste materials from transesterification process of raw oils.
- The results from various researches conclude that use of dual biodiesels can become a good source of environmental friendly alternative fuels.
- Stability of dual biodiesels for long term purposes can be studied.

CHAPTER 3:

3.1 Objective of the study

In this study or investigation, the two non-edible plants Thumba and Argemone mexicana are selected for the biodiesel production. On the basis of literature review, it has been concluded that until now, no research has been done on dual biodiesel blends of Argemone mexicana and Thumba oil in diesel engines. Following are some important points which signifies the objective of this study using dual biodiesel blends (B10, B20, B30 and B40) of AMME and TME:

- To compute various properties of both raw Argemone Mexicana and Thumba oil like calorific value, density, flash point, fire point, viscosity etc.
- To extract biodiesel from both Thumba and Argemone oil by means of transesterification process.
- Again computing same above properties of biodiesel of Thumba and Argemone.
- To perform investigation on dual blends of biodiesel (B10, B20, B30 and B40) obtained from both selected biodiesels.
- To analyze the performance characteristics like brake power, brake specific fuel consumption and brake thermal efficiency by changing load parameter.
- To study parameters of combustion like net heat release rate and cylinder pressure.
- To analysis the level of emissions from diesel engine using dual biodiesel blends of Argemone Mexicana and Thumba oil such as unburned hydrocarbons (HC), oxides of nitrogen (NO_X), carbon monoxide (CO), carbon dioxide (CO_2).

CHAPTER 4:

4.1 Review of literature

N. L. Jain et al. [1] conducted experiment using various blends of Thumba oil in diesel (B10, B20, B30, B50, B100) on a single cylinder, 4-stroke water cooled, 661cc engine developed by Kirloskar Ltd. in order to find various performance and emission characteristics parameters. The investigation revealed that the properties of preheated Thumba oil becomes almost similar to diesel at a temperature of 80-90 ^{0}C. The results also revealed that the CO emission was low at initial loading conditions but as the loading parameter increases, CO emission also starts increasing. The investigation also reveals that B20 is the only blend at which CO remains almost constant at all loading conditions. They observed that drop in CO emission in case using Thumba biodiesel is due to the higher concentration of oxygen content and hence efficient combustion process. However, from results it is further revealed that CO_2 decreases as the concentration of Thumba oil increases in diesel. This might be due to the higher viscosity of Thumba oil results in incomplete combustion and hence low CO_2. While comparing the results of B20 unheated Thumba biodiesel, preheated B20 Thumba biodiesel and diesel, it has been concluded that HC emissions from preheated B20 biodiesel (11 PPM) are lesser than unheated Thumba biodiesel (16 PPM) and diesel (20 PPM). The investigation also reveals that BTE decreases as the concentration of Thumba oil increases and explained that the lower BTE for higher blends of Thumba oil other than diesel is due to higher viscosity of vegetable oil which results in improper atomization and burning characteristics.

Amit pal et al. [2] revealed the properties by comparing Thumba biodiesel, Jatropha biodiesel and diesel characteristics on a four cylinder, water cooled, 4- stroke diesel engine which generates 39 KW at 500 rpm by varying load parameter using eddy current dynamometer. In this investigation, it has been found that up to 2500 rpm the torque for all the selected fuels remains almost same or in other words showing increment level in a similar manner. But as the speed increase beyond 2500 rpm, the torque for Thumba biodiesel (TB10, TB20) becomes higher as compared to Jatropha biodiesel (JB10, JB20) and diesel. The investigation further reveals that the BSFC for both Jatropha biodiesel and Thumba biodiesel is lower than diesel. This might be due to the lower calorific value and lower energy density in the above mentioned biodiesels. As for as the smoke opacity percentage is concerned, JB30 (Jatropha biodiesel) is having lower smoke emission percentage as compared to TB30 (Thumba biodiesel) whereas diesel is having smoke opacity level higher than both JB30 and TB30.

Sunilkumar R. Kumbhar et al. [3] The researchers performed an experiment to investigate the performance analysis of using Thumba oil blended with diesel on a single cylinder, four stroke, multi fuel, variable compression ratio diesel engine with a volume of 661.45 cc. From the obtained results, like at CR18, BSFC and BTE parameters of TB10, TB20 and brake power of Thumba biodiesel (TB40) displayed efficient performance. Similarly, emissions like HC, CO, and CO_2 of Thumba biodiesel showed reduced emission level (PPM). BTE for TB10 at compression ratio 18 is 36.31% which is better than all other relative blends of Thumba biodiesel and pure diesel fuel i.e. 33.27%. As for as the brake power level at CR18 is concerned, Thumba biodiesel TB40 showed effective performance (5.15 KW) as compared to other blends of Thumba biodiesel and pure diesel (5.07KW). From all the results obtained, Researchers concluded that Thumba biodiesel could be used as the best alternative fuel for existing diesel engines with less required modifications.

Ratnam Ramesh Gujar et al. [4] carried out an experimental investigation on a single cylinder, four stroke diesel engine at the rate of 1500 rpm in which researchers used various Thumba biodiesel blends like TB10%, TB20%, TB30%, TB40% and TB100%. Under different conditions, the data obtained from these blend samples were compared with diesel fuel. The results obtained like brake power, BTE, mechanical efficiency were found to be in an increasing pattern with respect to increase in load. From the results, it has also been found that HC emission decreases as load increases in all blends of Thumba biodiesel which might be due to increase in oxygen content in vegetable oil results in complete burning and hence less HC emission along with slight reduction in CO. Authors concluded from the results that Thumba biodiesel can be considered as best environmental friendly alternative fuel with less modifications in existing diesel engines.

Beena Mishra et al. [5] performed an experiment on a setup which consists of single cylinder, 4- stroke diesel engine in which compression ratio can be varied. Along with this setup, dynamometer is attached to change loading conditions. The parameters obtained from the experiment such as brake power, specific fuel consumption. Torque, BTE, exhaust gas temperature etc. During this test load was varied from 0-12 kg and speed is maintained at about 1550 rpm under all operating conditions. The results were obtained by analyzing two Thumba biodiesel blends i.e. B20 and B40 compared with pure diesel. From the results, brake thermal efficiency for biodiesel blend (B40) is 29.87% which is higher than 29.49% of diesel at the maximum load of 3.15 KW and compression ratio of 15. On the other hand, BSFC at CR15 for pure diesel is 0.37 kg/kw slightly lower than B20 and B40 consisting 0.38 and 0.39kg/kw. Among all blends, B20 is having lower BSFC for all compression ratio of 18 and 15. The results also revealed that exhaust gas temperature (EGT) for both blends like B20 and B40 increases related to diesel as Thumba oil concentration in biodiesel increased. During the same experiment, the smoke emission reduces compared to diesel for both B20 and B40 blends. This might be due to complete combustion because of having higher percentage of oxygen in biodiesels.

Ashish karnwal et al. [6] studied the production of biodiesel from Thumba oil by optimizing various parameters like temperature, amount of Methanol (alcohol), reaction time, amount of catalyst mixing etc. in order to increase the quantity of biodiesel yield. In this experiment, various required parameters were changed like temperature for reaction purpose changed from 50^0C to 65^0C. Molar ratio of alcohol to oil was varied from 3:1 to 15:1. Similarly, catalyst amount and process time varied as 0.5% to 1.5% (w/w_{oil}) and 10-90 minutes respectively. In this investigation, methanol was used as alcohol and KOH as catalyst. From the results, it was revealed that at the molar ratio of 6:1 and catalyst concentration of 0.75% KOH, ester conversion was recorded with 97.8% efficiency.

Pawar komal D. et al. [7] studied on transesterification of Thumba oil by using calcium oxide catalyst at a molar ratio of methanol in alcohol as (8:1) and a stirrer rotates at 650 rpm. Before allowing mixer or stirrer to operate, methanol is mixed with preheated oil. After the completion of reaction, unreacted methanol is eliminated by distillation and after 8-10 hours of time, settled biodiesel and glycerol are separated. Finally, after getting methyl ester, remaining water is removed by oven at a temperature of 100^0C to get final pure diesel. ***Vandana Kaushik et al.*** [8] conducted test on a diesel engine in order to find out the performance characteristics for various lower Thumba methyl ester blends with diesel like TME10, TME20, TME30 for various compression ratios. From the results, it has been analyzed that the brake thermal efficiency keeps on increasing for diesel fuel as there is increase in load but there is slight decrease in BTE for all other TME blends. Among all blends, TME20 in which concentration of Thumba oil in diesel is 20% is having higher brake thermal efficiency. But as the percentage of Thumba oil concentration is increased i.e. TME30, there is slight reduction in BTE. The results also reveal that specific fuel consumption for all blends is higher than diesel fuel under all load conditions. Moreover, exhaust gas temperature was also found increasing for all blends other than diesel at different high loads. But TME20 is having lower EGT.

Ankur Nalgundwar et al. [9] conducted an experiment using a single cylinder, four stroke, DI diesel engine provided with air cooling system. The test was performed to find out various characteristic parameters like combustion and emission parameters with respect to change in loading conditions using dual biodiesel blends of Jatropha and palm biodiesel. In this investigation various blends like D0JB50PB50 (0% diesel, 50% Jatropha biodiesel and 50% palm biodiesel), D20JB40PB40, D40JB30PB30, D50JB25PB25 etc. The results revealed that brake power for blend D90JB5PB5 is 4.65% higher than other blends because as the concentration of Jatropha and palm biodiesel increases, brake power reduces accordingly. The author clarifies that it might be due to higher viscosity and lower calorific value of biodiesel. In the results, BSFC reduction was about 2.55% for D60JB20PB20. But with increase in biodiesel concentration, BSFC also increases accordingly. For lower blends like D80JB10PB10, D60JB20PB20, there is a small increment of about 3.2%, 2.1% in BTE respectively but for higher biodiesel concentrated blends such as D20JB40PB40 and D0JB50PB50, there is significant increase in BTE by 12% and 15.40% respectively. While considering EGT for all blends, it was found that for lower blends EGT level is lower but for higher blends EGT increases due to incomplete combustion. Similarly, CO, HC reduces significantly but there was slight increase in NO_X emission.

K. Srithar et al. [10] revealed results for various parameters such as calorific value, specific gravity, kinematic viscosity, cetane number, flash point using dual biodiesel blends of Jatropha biodiesel and Pongamia pinnata biodiesel. From results, it has been indicated that viscosity and calorific values for DPJ10 blend are almost similar to diesel values. Further the results displayed that DPJ biodiesel has higher cetane number than pure diesel. One more advantage for this dual biodiesel is easier to store and safe transport because of having higher flash point. As for as the performance analysis is concerned, DPJ10 and DPJ20 is having higher thermal efficiency almost closer to diesel fuel. From the outcomes of emission parameters, it was revealed that both HC and CO concentrations for considered biodiesel blends are having lower values than of diesel fuel. This might be due to the complete combustion due to higher oxygen content in biodiesels. Among results, it was also concluded that NO_X emission was higher.

M. K. Parida et al. [11] carried out the experiment on a 4-stroke, single cylinder, variable compression ratio (VCR) diesel engine to find out various combustion parameters under different loading conditions for Argemone mexicana biodiesel blends. In this test, author compiled various results by using two blends of Argemone Mexicana i.e. B20 and B40 along with pure diesel. The conclusions for combustion pressure indicated that at a fixed compression ratio of 17.5 and fixed loading condition of 8kg exerted by a dynamometer, B40 blend indicates higher peak pressure (57.4 bar) than B20 and pure diesel having peak pressures 57.1 and 54.4 bars respectively. The higher combustion peak pressure for B40 biodiesel blend is due to shorter ignition delay. Considering results for net heat release rate, it was revealed that the net heat release rates for pure diesel, B20 and B40 are 56.23, 69.59 and 68.15J/CA.

P. Taylor et al. [12] made experimental investigation on a four stroke diesel engine fueled with neem oil, which was blended with some quantity of alcohol. During this experimental observation, results were revealed for blended mixture sample in which neem oil was blended with 20% of alcohol manually. Results indicated that neem-alcohol shows comparative better brake thermal efficiency than neat neem oil. Smoke opacity was also found low in concentration for neem-alcohol blend related to neat neem oil. Reduction in NO_X emission was also found and similarly CO, HC emission was also recorded in lower quantity in neem oil blended with alcohol compared to neem oil alone.

P. Kumar et al. [13] conducted investigation to find out the performance and emission parameters using B50 (50% of Jatropha biodiesel + 50% diesel) in a direct injection diesel engine. During this test, different compression ratios were used to find out the results i.e. 14,16 and 18. It was revealed that B50 is having higher brake power and it was also concluded that for a compression ratio of 18, B50 biodiesel blend shows maximum BTE. Under the same conditions, results also displayed that HC emission is lower. This might be due to the higher cetane number of biodiesel and higher oxygen content. Since having higher oxygen content in biodiesel, it was found that there is lesser CO emission by B50 biodiesel blend. Finally, the authors stated that B50 could be a good choice of alternative fuel in an engine in future.

K. Srithar et al. [14] examined the impact of using dual biodiesel blends of Mustard oil and Pongamia pinnata oil in various proportions with diesel. This investigation was performed on a single cylinder, air-cooled, high speed direct injection diesel engine at different loads maintaining constant speed of 3000 rpm. In this test, mainly focus was diverted towards various parameters such as CO, CO_2, HC, NO_X and smoke emission. During this test, the various dual biodiesel blends were used with content proportions as: Blend-A, in which diesel concentration is 80%, PPEE and MEE concentration is 5% and 5% by volume respectively. Similarly, Blend-B (PPEE 10%, MEE 10%, diesel 80%), Blend-C (PPEE 20%, MEE 20%, diesel 60%), Blend-D (diesel 40%, PPEE 30%, MEE 30%) and Blend-E (diesel 20%, PPEE 40%, MEE 40%) were developed for testing purpose. Among all blends, it has been observed that Blend-A and Blend-B are having higher calorific values. The results further revealed that specific fuel consumption for all blends decreases with increase in brake power. Regarding brake specific energy consumption, all selected blends shows higher BSEC as compared to diesel due to calorific values. Similarly, mechanical efficiency is higher for lower biodiesel blends i.e. Blend-A (79.3%) as compared to diesel (78.2%). The results also revealed that for Blend-A and Blend-B, concentration of CO and CO_2 is lower than diesel at higher loads. NO_X and HC for all blends also follows the same path i.e. increases as load is increased.

A. M. Liaquat et al. [15] presented the work which investigates the performance and emission parameters on a DI diesel engine considering coconut biodiesel blends. In this test, three biodiesel blends were used such as DF (containing 100% diesel fuel), CB5 (containing 5% coconut biodiesel and 95% diesel fuel) and CB15 (containing 15% coconut biodiesel and 85% pure diesel). At 100% load, the test was performed in order to find out the engine performance parameters maintaining throttle position with 100% wide open for various variable speeds of about 1500 rpm to 2400 rpm at 100 rpm intervals. On the other hand, at 2200 rpm with 100% and 80% throttle position, emission parameters have been investigated. From the results obtained, it has been analyzed that there is abrupt decrease in brake power and torque but higher specific fuel consumption was observed for all biodiesel blends at various speed parameters as compared to diesel fuel alone. As for as, emission parameters are concerned, HC, CO concentration was recorded in lower quantity but higher CO_2 and NO_X emission was obtained on comparing with diesel fuel.

Ashish Sithta et al. [16] performed an experiment using various blends of Argemone oil and diesel in various proportions such as B0 (pure diesel), B10 (10% Argemone, 90% diesel), B20 (20% Argemone, 80% diesel), B40, B60 and B80 in order to observe various performance and emission parameters on a four stroke, single cylinder, DI diesel engine. During this investigation, various parameters like fuel consumption, BTE, CO, HC and smoke density were observed. Among the results, B20 is having higher BTE (28.56%) as compared to diesel (27.81%). The BSEC was also found slightly closer to diesel. Emission results also shows significant reduction using various Argemone oil biodiesel blends related to diesel. From results, it was revealed that Argemone biodiesel could become a good source of fuel for diesel engine sin future.

Amit pal [17] presented the conclusions of performance and emission analysis of Jatropha biodiesel blends using four cylinders, four stroke, diesel engine to which a dynamometer is attached for various loading conditions. Engine tests were carried out to get comparative results of engine torque, BP, CO, HC, NO_X and smoke compared with diesel fuel. For this test, three blends were developed such as B10 (10% Jatropha and 90% diesel), B20 (20% Jatropha and diesel 80%) and B30 (Jatropha 30% and diesel 70%). From the results, it has been analyzed that the values for brake power and engine torque are almost nearer diesel at initial speeds i.e. up to 2500 rpm. But beyond this speed, there is reduction in above mentioned two parameters compared to diesel values. For the blends B10 and B20, BSFC decreases or becomes equal to diesel as load increases and BSEC is having lower values than diesel under all conditions. This might be due to larger amount of oxygen content due to which CO emission is low as compared to diesel. Similarly, experimental results indicated that smoke, HC emissions shows reduction than that of diesel fuel, excluding NO_X emission which is slightly higher.

Suresh Kumar et al. [18] concluded the results of emission and performance analysis for Pongamia Pinnata methyl ester (PPME) blended with diesel using a DI compressed ignition diesel engine. During this test various parameters like, BSEC, BSFC, HC, CO, CO_2 and NO_X were investigated of PPME with diesel in various concentrations. It has been recorded that as the load increases, there is reduction in BSFC but as the concentration of PPME increases, BSFC increases accordingly. This might be due to the higher viscosity and lower calorific values. Blends B40 and B60 releases low emissions as compared to diesel. This might be due to the fact that biodiesel consists lower carbon fuel than diesel fuel. Similarly, HC emission also reduces when load increases. NO_X emission for all the blends indicated an increase path due to high temperature and higher oxygen content.

Parmjit Singh et al. [19] performed an experiment in order to reveal the performance parameters for various Argemone mexicana biodiesel blended with diesel in various proportions such as AB10 (Argemone biodiesel 10% and 90% diesel), AB20 (Argemone biodiesel 20% and 80% diesel) under different loading conditions (0%, 20%, 40%, 60%, 80% and 100%) and at constant RPM using single cylinder, four stroke diesel engine along with eddy current dynamometer. The parameters include, brake power, BTE, BSFC. Before testing method, Argemone biodiesel was prepared by transesterification in order to remove fatty acids and glycerol to form methyl esters. For transesterification process, author used methanol as alcohol and sodium metal as catalyst. Operating conditions for experiment were maintained with molar ratio (1:6, 1:3, 1:9 oil to methanol), time of reaction (60 min, 90 min, 120 min) and reaction temperature (55^0C, 65^0C, 75^0C). It was found that most preferred molar ratio for transesterification is 1:6 along with reaction time, 120 min and 75 ^{0}C reaction temperature. After results compared with diesel, it was observed that the two biodiesel blends (AB10 and AB20) have shown improved brake thermal efficiency, B.P, BSFC.

Agarwal D. et al. [20] conducted an experiment on a single cylinder, 4-stroke, water cooled, constant speed DI diesel engine in order to analyze the impact of reducing viscosity of Jatropha oil by preheating and blending with diesel. It was revealed from the results that when Jatropha is heated before injecting into combustion chamber, its BSFC and exhaust temperature factors reduces other than unheated Jatropha oil. Moreover, Brake thermal efficiency for heated Jatropha biodiesel was measured higher than BTE for unheated Jatropha biodiesel. It was further found that HC and CO increases as the concentration of Jatropha is increased with diesel. This might be due to higher viscosity, lesser vaporization and improper combustion. Finally, it was concluded by authors that Jatropha could be used as an impressive alternative fuel for diesel engines in agriculture and irrigation sector.

Dipti Singh et al. [21] performed the extraction of biodiesel from Argemone Mexicana in a laboratory. In this extraction process, transesterification method was conducted in two steps to remove the acid value. During initial process of removing acid value, acid catalyst was used and in next step, alkali catalyst was used. Molar ratio of 5:1 (oil to alcohol) was used for alkali catalyst. The alcoholic methoxide mixture was developed by mixing $20cm^3$ methanol by volume and sodium hydroxide (catalyst) by 0.35g. Alcoholic methoxide mixture was then stirred in a stirrer vigorously for twenty minutes. The mixture prepared then transferred to a reactor containing $100cm^3$ of free oil (Argemone mexicana oil). Again, mixture was stirred for one hour at a temperature of 55^0C to 60^0C. As the reaction completes, the mixture attains a transparent brown color. Finally, the whole mixture was poured in a separate container and allowed to settle for some time. After settling process, two separate layers gets formed in which above layer was pure methyl ester and the layer at bottom is glycerol. In order to further remove the catalyst content, methyl ester was used to wash with water.

Knothe et al. [22] concluded that before 1937 Belgian Congo, ethyl esters were replaced as diesel fuel. In this investigation, it was revealed that a lot of research development occurs after 1970s up to 1980s due to high price fuel crisis. Initially many researchers recommended to use straight vegetable oils as biodiesel. But it gives rise to many problems like oil thickening, oil dilution in crankcase, cylinder and injector deposition due to excess viscosity in case of straight vegetable oils. It was further revealed that after reducing the viscosity of vegetable oil in nearer to diesel by many processes makes it possible to use biodiesel within the diesel engines without modification.

Fengxian Qiu et al. [23] investigated yield of fatty and methyl ester (FAME) biodiesel by performing transesterification of the mixture of rapeseed and soybean oil. In this process, catalyst NAOH was used. The study generally indicated the effect of molar ratio, amount of catalyst, time of reaction and reaction temperature over yield. An alternative to decrease in reaction temperature was tested by using hexane into the reactants and the results were improvement in conversion process. It was found that about 94% of methyl ester yield was recovered for 5:1 (molar ratio, methanol to oil), 55^0C (reaction temperature), catalyst weight (0.8 wt. %) and 2-hour time of reaction.

Osmano S.V et al. [24] selected waste cooking oil biodiesel blended with diesel oil for its physical and chemical properties. Various characteristics were measured like density, viscosity and concentration of Sulphur. It was found from the study that as the concentration of biodiesel increased, viscosity and density increases accordingly while Sulphur content decreases. The investigation revealed that B20 (20% waste cooking oil and 80% diesel) shows significant performance and emission characteristics even better than diesel. It was also found that Sulphur content reduces below 50ppm by blending 83% of waste cooking oil in diesel.

Fangrui Ma et al [25] referred that due to the best economic and environmental friendly characteristics, more attention is being diverted towards the development of biodiesel as fuel in diesel engines. But the main obstruction in commercialization of biodiesel is its production cost. Many researchers concluded that refinement of by-product glycerol to make it a high quality for many additional purposes can reduce the biodiesel production cost to a large extent. Many researchers have suggested number of techniques to reduce the viscosity of straight vegetable oil to make them usable for commercial diesel engines like transesterification, pyrolysis, thermal cracking etc. this reduction in viscosity eliminates many problems like carbon deposit, contamination of lubricating oil etc.

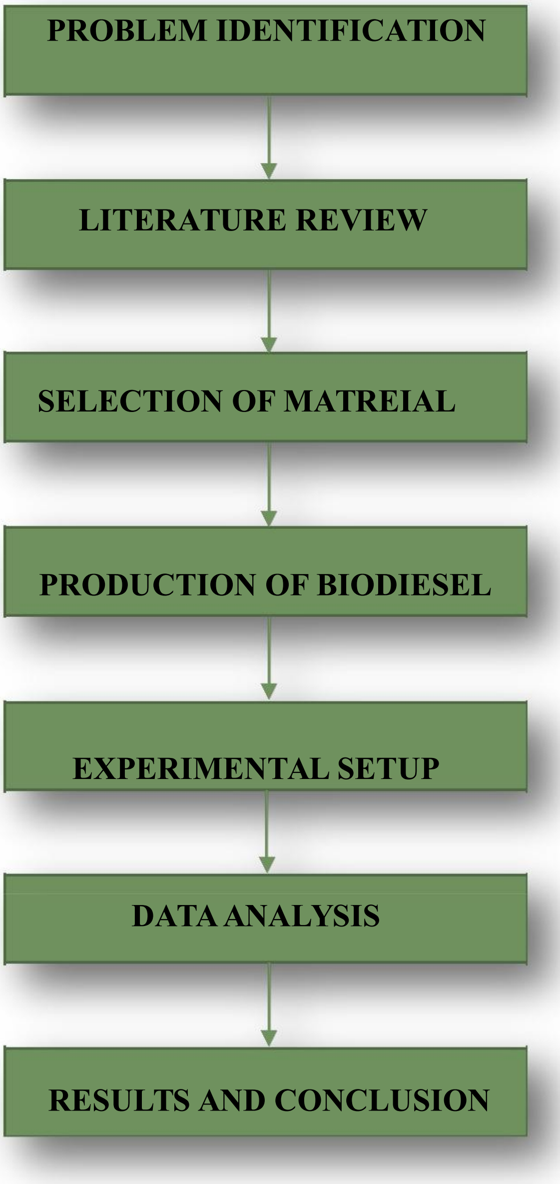
Ashawani kumar et al. [26] studied the importance of non-edible oils as most preferred biodiesels instead of edible oils in India. The researcher revealed that as India is the most developing and populated country in the world, it is impossible to use edible oils as biofuels in order to eliminate the chances of fuel crisis as there is huge gap in demand and supply of resources. Researchers have further revealed that India is a good producer of various non-edible oils like Jatropha, Pongamia Pinnata (Karanja), Argemone Mexicana etc. It has been estimated that by the year 2020, there will be about 20-22% of biofuel operated vehicles available on roads of India, Brazil, China and Europe. This estimated data enable India to research as much as possible in cultivation of non-edible oils.

Rakesh Kumar et al. [27] performed study on a single cylinder, diesel engine using dual biodiesel blends of Mahua and Argemone Mexicana. In this investigation, performance and emission characteristics were evaluated by changing engine load and biodiesel concentration. From the study, various parameters like peak pressure, volumetric efficiency, heat release rate and indicated thermal efficiency were measured. From the results, it was revealed that B20 (Diesel 80%, Argemone 10% and Mahua 10%) shows 1.31% hike in volumetric efficiency. Heat release rate was also found maximum for the diesel instead of dual biodiesel blend because of low calorific value. Similarly, B40 shows higher peak pressure than diesel fuel by 1.75 bar.

CHAPTER 5:

5.1 Research methodology (Test procedure and operating conditions)

In the chapter of research methodology, special focus is being diverted towards the experimental setup used and method of carrying experimental investigation which are being considered as important factors for the successful research study. Below is a block diagram which indicates the whole research methodology for this study:



5.2 Selection of material

For this study, two non-edible vegetable oils are selected like Thumba and Argemone Mexicana.

5.2.1 Thumba vegetable oil

Thumba Biodiesel (Citrullus Colocynthis) generally referred as Colocynth, belongs to a family of Cucurbitaceous. This Biodiesel is a non-edible vegetable oil, generally named as Indrayan in Hindi and Bitter Apple in English. This plant is being considered as a drought resistant type of specie having a long deep root system, mostly found in many areas of Africa and Asia. In India, this type of plant is mainly grown in Rajasthan and Gujarat deserts. This plant also belongs to a Creeper plant species family and largely found in sandy soil. It does not require any type of special care and its full growing cycle is 180 days approximately. Nowadays, the oil of this plant is mainly used in soap industries. The qualities of this plant related to diesel oil other than 'Jatropha' makes it more dominant. Hence due to its small crop cycle, makes it an important part in rural economy. Thumba fruit is almost similar to watermelon and the color of seeds are grey in color. This is being considered as best energy future energy source of fuel for India due to various properties. Its use is not bound only to oil sources or biofuels but for medicinal values, it also plays a very important role. One of the best advantage for Thumba oil is that it can be cultivated even on poor soils like sandy soils and also requires less amount of moisture and care. The yield of oil from Thumba seeds varies between 35% to 43% and can play a vital role in improving rural employment in India. The seeds were bought from Ludhiana market in Punjab.Qualities of Thumba oil are enlisted in below table-1

Table-1: Qualities of Thumba plant

S. No.	Characteristics	Thumba plant
1.	Plant type	Creeper
2.	Crop Cycle	6 months
3.	Soil type	Sandy soil
4.	Manure	No special requirement

Figure-5.1: Thumba plant with fruit

Figure-5.2: Thumba seeds

5.2.2 Argemone mexicane vegetable oil

In this research study, the main aim is to investigate the analysis of using dual biodiesel blends. From the literature review, number of researches have been carried out using various non-edible dual biodiesel blends like Jatropha, Karanja, Mahua, Pongamia pinnata etc. But they need special care and attention in their cultivation. Hence, after selecting Thumba vegetable seed oil, Argemone Mexicana seed oil was selected as a second non-edible vegetable oil to prepare this dual biodiesel blend. Argemone Mexicana classified among poppy family species which was initially found in Mexico. This is the reason that as a suffix, mexicana is used. After many studies have been conducted on this vegetable oil as biodiesel, many other countries have started recognizing this as among best source of biodiesel because of its higher oil yield (34%-40%) like India. It is not used only for biodiesel fuels but also for medicinal values as well. In India, commonly it is reffered as Satyanashi. Another advantage for its cultivation is that poor soil and waste land can be used. Flowers produced from these plants are yellowish in color and the height of the plant is generally found to be 0.12m. As these plants are drought resistant hence, less attention is required. Argemone seeds are almost similar to mustard seeds with black in color. Argemone Mexicana plants can also be grown in such areas where rainfall is recorded in lower quantity. Mostly these types of plants are found along roadsides with thorny fruits. Single step transesterification is required to extract biodiesel from these seeds due to low content of fatty acids. Therefore, biodiesel production process can be completed at low cost related to other non-edible oils.

Figure-5.3: Argemone plant

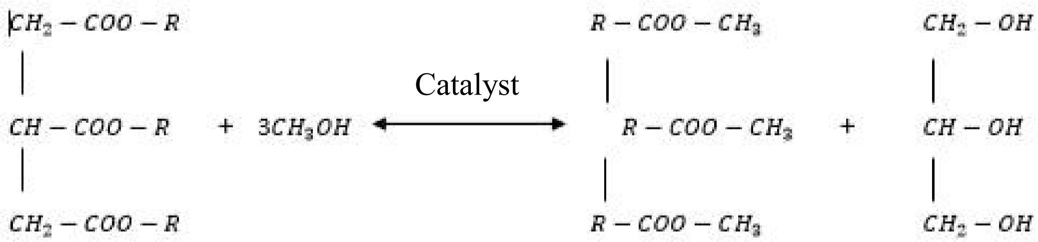
Figure-5.4: Argemone Mexicana seeds

5.3 Production of Biodiesel

In this study, the two plants named as Argemone Mexicana and Thumba are selected in which biodiesel production will be carried out by means of transesterification process as discussed below:

5.3.1 Transesterification

Transesterification also referred as Alcoholysis, defined as the removal of fatty acid esters or biodiesel and glycerol in the form of byproducts from a chemical reaction including use of alcohol (methanol or ethanol) and oil or fat (triglyceride). This process is generally used to decrease the viscosity parameter of triglycerides. Below is general equation represents Methanolysis means methanol is used for the reaction of removing FFAEs from triglycerides:



Triglyceride 3-Methanol 3-Biodiesel Glycerol

Figure-5.5: General Transesterification equation

From the equation, the free fatty acids removed are referred as biodiesels. Hence in order to remove the viscosity for both the selected vegetable oils like Thumba and Argemone Mexicana, the above discussed transesterification reaction for effective results carried out for this investigation at a temperature of about 60^0C for initially mixed 1.5 liter of Argemone oil and at the 400ml of methanol and 10 gram of catalyst, potassium hydroxide after dissolving for 10-15 minutes poured into the oil. Similarly, the same process will be done for Thumba biodiesel production but instead of 400ml of methanol, only 390ml of KOH is poured. After the completion of reaction, mixture prepared is allowed to settle. After sometime, two separate layers gets created in which the bottom layer or glycerol is drawn off while the top most layer is removed and washed so that any remaining glycerol, catalyst or alcohol is eliminated. The top layer is generally referred as FAMEs or Biodiesel. During transesterification process, there are various parameters which should be considered very keenly to make the process of Alcoholysis effective as discussed below:

- Oil temperature plays a very important role in conversion of vegetable oil to biodiesel. Many researchers concluded that heating the vegetable oil before mixing the same heated oil with catalyst increases biodiesel recovery.
- Reaction temperature is another important parameter which influences the rate of reaction strongly. Generally, it has been studied that maintaining the temperature at 55^0C to 70^0C in a mixture of vegetable oil and catalyst increases the biodiesel production efficiency.
- One more important variable i.e. molar ratio (alcohol to oil) which also affects the conversion efficiency. Many researchers concluded that molar ratio of 6:1 subjects in increase of removing of glycerol from vegetable oil leaves biodiesel with zero fatty acids.
- In order to increase the conversion reaction, catalysts are also being used in which alkaline catalysts are more commonly used. It has been found that 94%-99% yield of biodiesel or esters can be extracted from vegetable oils by adding only 0.5%-1% of catalyst by weight.

5.3.2 Blend Preparation

After completing the final separation process, following are the four blends which will be prepared for further testing and analyzing process:

- B10 (Argemone 5% + Thumba 5% + Diesel 90%)
- B20 (Argemone 10% + Thumba 10% + Diesel 80%)
- B30 (Argemone 15% + Thumba 15% + Diesel 70%)
- B40 (Argemone 20% + Thumba 20% + Diesel 60%)

5.3.3 Process for production of Biodiesel

Below is a flow chart which clearly indicates that what are the processes used in transesterification in yielding of biodiesel from raw vegetable oils:

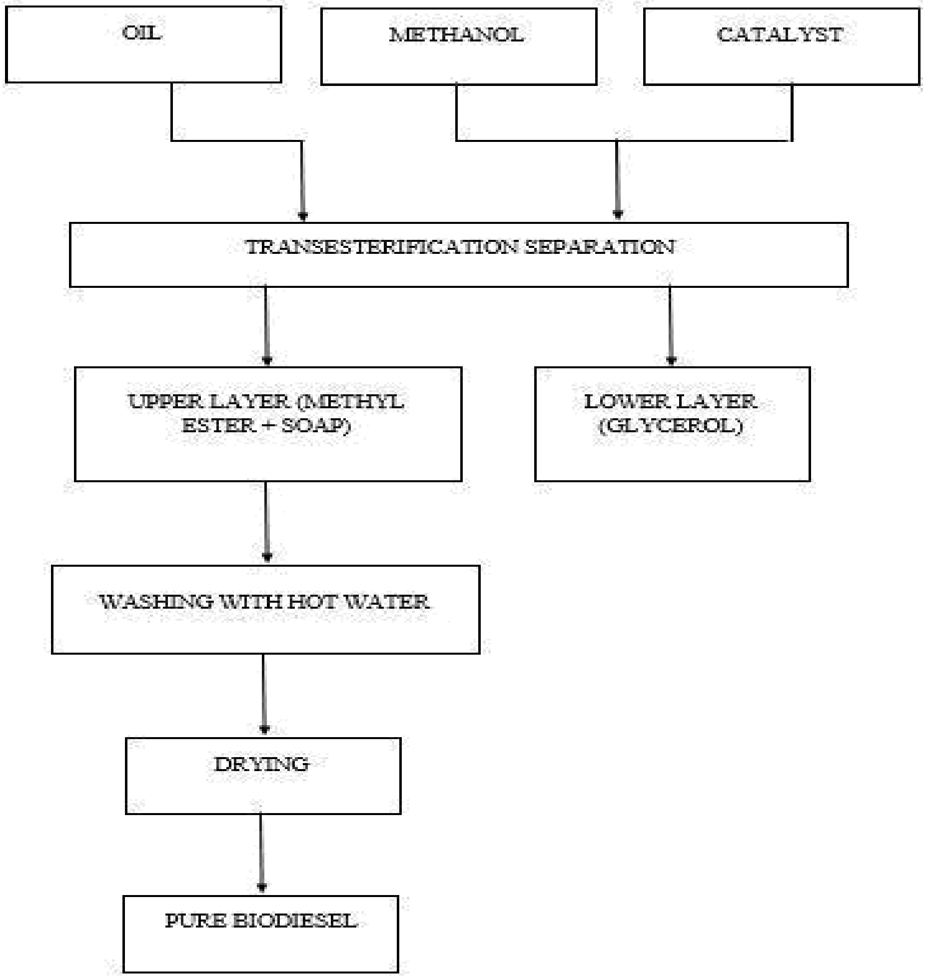


Figure-5.6: Biodiesel production flow chart

5.4 Engine Testing

After preparing the required blends, the investigation will be carried out on a four stroke, single cylinder, variable loading engine using the selected blends. The main focus while testing is to find out the emission level for various pollutants like Hydrocarbons (HC), Nitrogen oxide (NOx), Carbon monoxide (CO) etc. Along with these pollutants, some other parameters will be also evaluated like Brake specific fuel consumption, Brake power, Brake thermal efficiency, Brake specific energy consumption.

CHAPTER 6:

6.1 Equipment, Material and Experimental setup

6.1.1 Test Accessories

There are various properties which needs to be measured after biodiesel yielding to find their comparison with diesel. Some important properties which will be checked in further experimental work like, density, viscosity, fire point, flash point, viscosity, specific gravity and calorific value. Following are the required instruments used to measure all above discussed properties at Sardar Swarn Singh National Institute of bio energy (SSS NIBE):

6.1.1.1 Flash point and Fire point apparatus

Flash point may be defined as a temperature at which flashing takes place as the fuel vapors exposed to spark or flame. From literature survey it was revealed that flash point is always higher for biodiesels which makes them easy to store and handle as compared to diesel. The fire point is referred as the temperature at which fuel starts burning more than five seconds. Below figure-6.1 is an apparatus used to measure the two values.

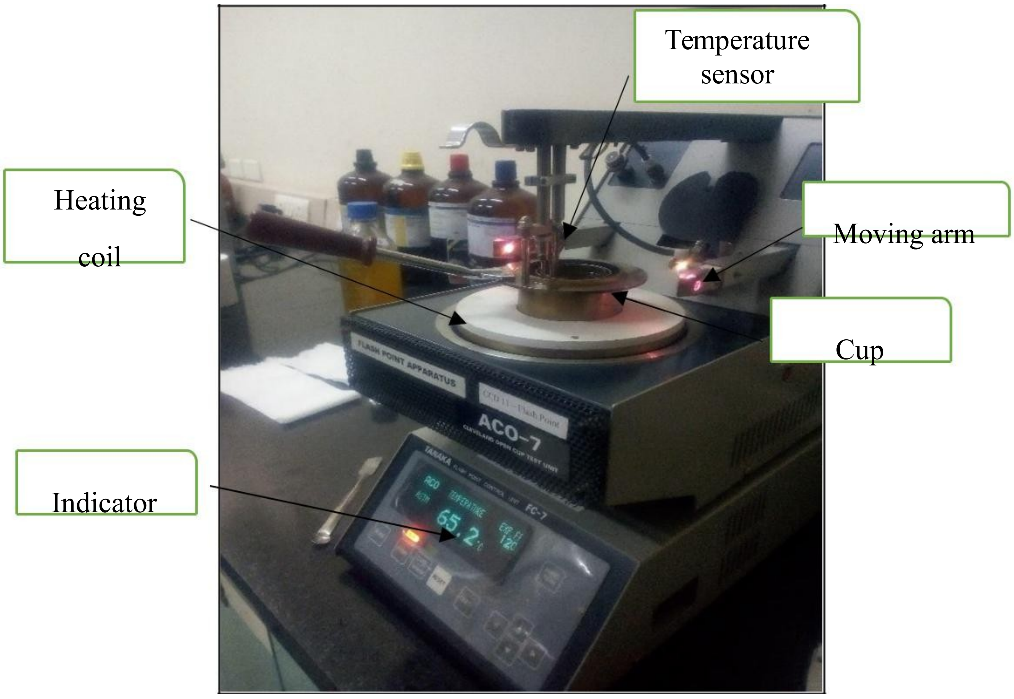


Figure-6.1: Fire point and flash point apparatus

6.1.1.2 Lawler model viscometer bath

Viscosity is an another important parameter used to measure the injection properties of biodiesel by the help of viscometer in order to select the best preferred fuel biodiesel blends without negative impacts during combustion or injection. Below is a figure 6.2 which is a viscometer by Lawler

Figure-6.2: water bath viscometer

6.1.1.3 Petroleum density meter

Density may be defined as the mass per unit volume which plays an important role to select most preferred biodiesel blend using density meter. While measuring density, blend proportion can be altered to prepare blend resulting in efficient engine properties. Below is a Figure-6.3 which is a density meter:

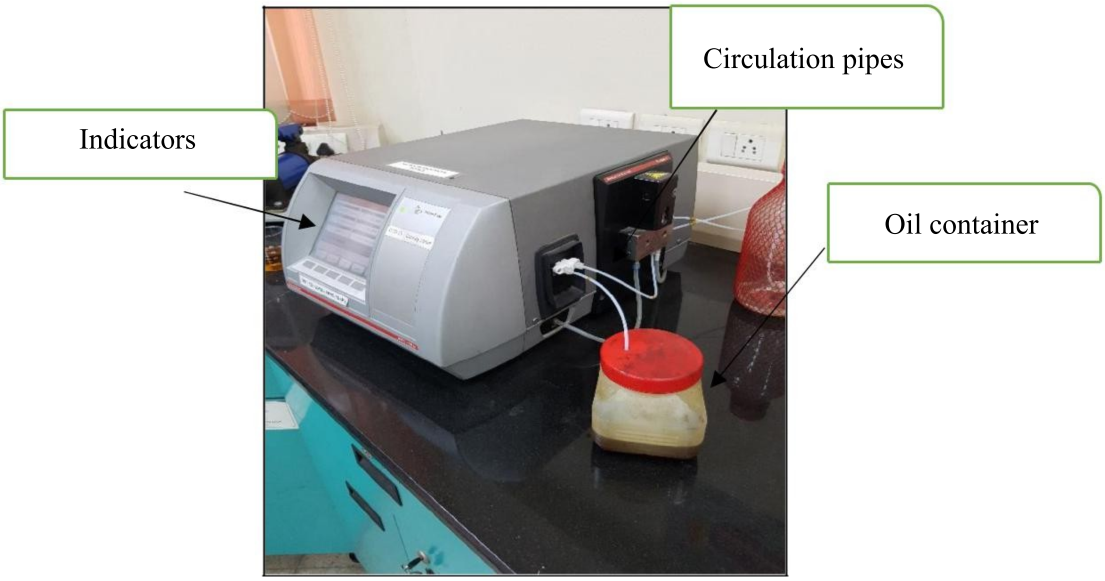


Figure-6.3: Petroleum Density meter

6.1.2 Biodiesel setup

In order to perform transesterification process for extraction of biodiesel from two selected non- edible vegetable oils like Argemone Mexicana and Thumba, the biodiesel setup at Sardar Swarn Singh Institute of Bio energy (SSS NIBE) as shown on figure 5 will be used. In this setup, the main components are: stirrer, thermometer and condenser. Among these three components, stirrer is used to properly mix the combination of methanol, vegetable oil and catalyst (KOH) for effective reaction process. The thermometer is used to indicate the temperature for different conditions and condenser usually used to stop the wastage of methanol during reaction. The setup also consists heater external jackets to maintain mixture temperature at a constant level. From the previous literature reviews, it has been found that at a temperature of about 55-60^{0}C and at a continuous stirring, higher yield value of biodiesel was recorded.

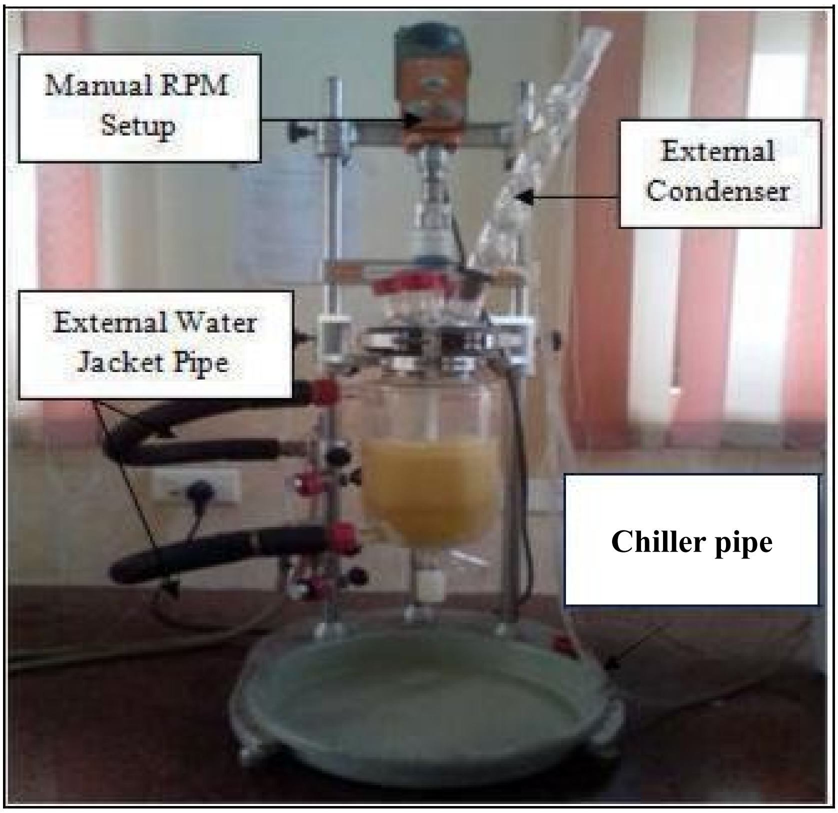


Figure-6.4: Biodiesel setup

6.1.3 Engine setup

As the production of biodiesel process gets completed, the biodiesel as a byproduct will be used for analysis of performance and emission characteristics. For the investigation process, the engine setup at (Sardar Swarn Singh Institute of Bio energy) at Kapurthala, Punjab as shown on figure 6 below will be used. The engine setup consists of a single cylinder, 4- stroke with variable loading parameter capability. In order to obtain the emission level, the eddy current dynamometer attached to the setup will be used to vary the loading parameter. Th emissions which will be measured are HC, NO_X, CO_2 and CO. In order to cool the engine testing setup, cooling water is used to circulate by means of pump. At the cylinder head, piezoelectric pressure transducer is used to record the change in pressure. The test will be conducted for various dual blends of Mexicana Argemone and Thumba like B10, B20, B30 and B40.

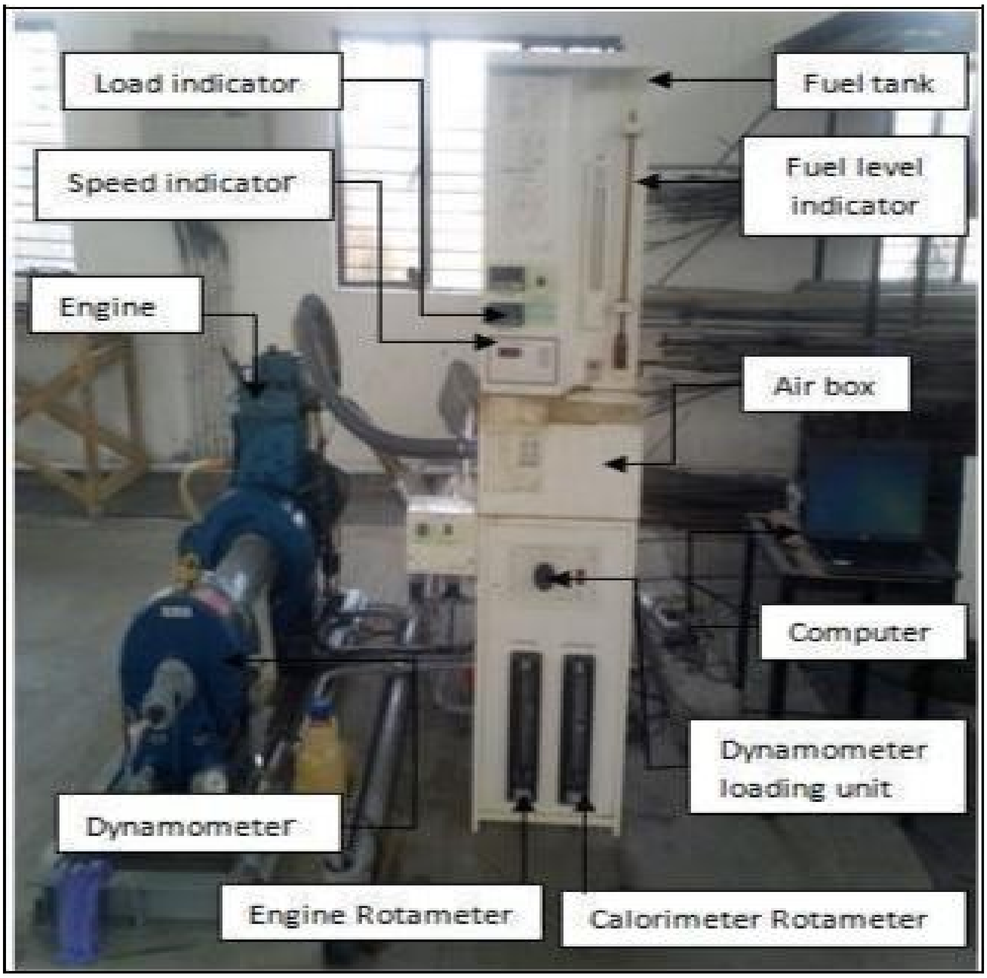


Figure-6.5: Engine testing setup

Below is a Table-2 which is showing specifications for engine testing setup which will be used for further testing process:

Table-6.1: Specifications of engine setup

ENGINE	SPECIFICATIONS
Engine Type	Single Cylinder, 4 Stroke, Water Cooled, Naturally Aspirated Diesel Engine
Rated power	3.5Kw @ 1500 RPM
Piston Bore, d	87.5mm
Stroke length, L	110mm
Connecting rod length, l	234mm
Variable compression ratio	12:1 to 18:1

CHAPTER 7

7.1 Experimental work

Before starting the process of transesterification to yield biodiesel, both the two selected vegetable oils like Thumba and Argemone Mexicana were purchased from Ludhiana market in Punjab. Both were easily available in the market. The most important parameter which plays a very important role in selecting these two oils is that both these two oils are non-edible oils which means less effect on food security. As the velocity of these two raw vegetable oils was higher, hence in order to make them usable for engine testing, transesterification process was used to their viscosity nearer to affordable range. The transesterification process was conducted at Swarn Singh National Institute of Bio energy (SSS NIBE), Kapurthala, Punjab. The figure-7 and figure-8 below shows bottles filled with raw Thumba and Argemone oil respectively.

Figure-7.1: Thumba oil

Figure-7.2: Argemone oil

Before starting transesterification process for Thumba oil, Fatty acid value measured was 4.4 MgKOH/gram of sample, which concludes one-step transesterification can be used. After that, 1500ml of oil was poured into the reactor and heated @ 65^0C by means of hot water circulation. As the oil attained some temperature, dissolved solution of 390ml of methanol and 10gram of KOH was poured into the oil for removing glycerol, soap etc from raw Thumba oil. The reactor was continuously stirred for about 2 hours and then the whole mixture is poured with water 5-10 times to eliminate impurities like soap, glycerol etc as shown in below figure-9. After proper washing, the mixture was

Figure-7.3: Washing with water

allowed to settle in a separating funnel as shown on figure-10 below for two days so that any heavy matter will settle at the bottom to be removed.

Figure-7.4: Separation process

Finally, after heating at 100-105^{0}C in a hot air oven the pure Thumba biodiesel is shown on figure-11 below:

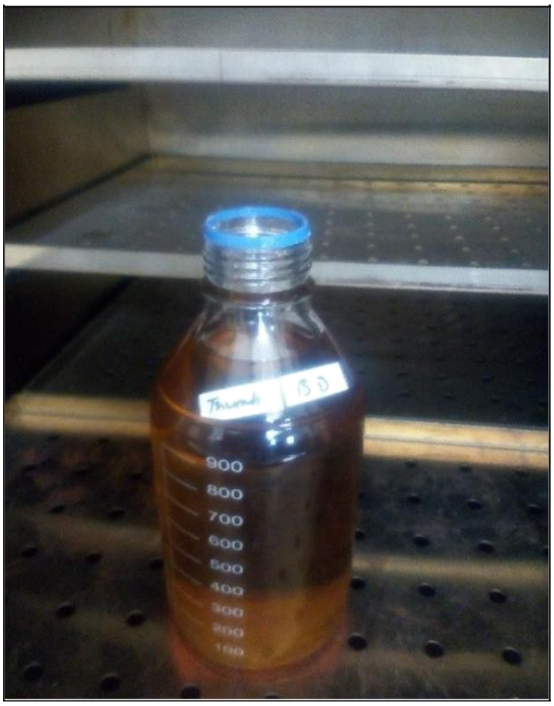


Figure-7.5: Thumba biodiesel (B100)

For Argemone, the measured fatty acid value was 12.27MgKOH/gram of sample. This results in two-step transesterification process because of higher acid value. The remaining procedure for Argemone biodiesel production was same as in case of Thumba biodiesel production but the methanol concentration was 400 ml for 1500ml of oil. The figure-12 below shows the final B100 Argemone biodiesel.

Figure-7.6: Argemone Biodiesel (B100)

7.2 Measured fuel properties

Following are the two tables which shows properties for both thumba and argemone biodiesel using test accessories at Sardar Swarn Singh National Institute of Bio Energy (SSS NIBE):

Table-7.1: Thumba biodiesel properties

Properties	Thumba biodiesel	Diesel
Density @15^{0}C, g/cm^3	0.872	0.828
Specific gravity @ 20^{0}C	0.890	0.827
Calorific value, MJ/Kg	38.1	42
Flash point, ^{0}C	191	68
Fire point, ^{0}C	201	72
Viscosity @ 40, cSt	5.37	2.80

Table-7.2: Argemone biodiesel properties

Properties	Argemone biodiesel	Diesel
Density @15^{0}C, g/cm^3	0.913	0.828
Specific gravity @ 20^{0}C	0.895	0.827
Calorific value, MJ/Kg	39.1	42
Flash point, ^{0}C	205	68
Fire point, ^{0}C	217	72
Viscosity @ 40, cSt	5.67	2.80

CHAPTER 8

8.1 Expected outcomes

Biodiesel is most effective and renewable alternative fuel and can provide stable energy supply. Moreover, biodiesel obtained from non-edible oil resources can eliminate food security problems as in case of edible oils. Production of biodiesel can play a significant role in rural development and rural employment. It has been researched that blending of biodiesel with diesel can reduce the cost of fossil fuels to a large extent. Some possible important expected outcomes will be:

1. The outcome results regarding performance of engine is expected to be far better than diesel fuel.

2. The brake specific fuel consumption (BSFC) for higher loads is expected to be nearer to diesel fuel.

3. Also for the mechanical efficiency and thermal efficiency, it is expected to be more for B20 Blend than diesel fuel.

4. For emissions like Unburnt Hydrocarbons, CO_2, and CO are expected to be low in concentration for (B20) as compared to diesel fuel. But NO_x levels are expected to be high possibly due to higher temperature distribution during combustion.

CHAPTER 9

9.1 Summary and Conclusions

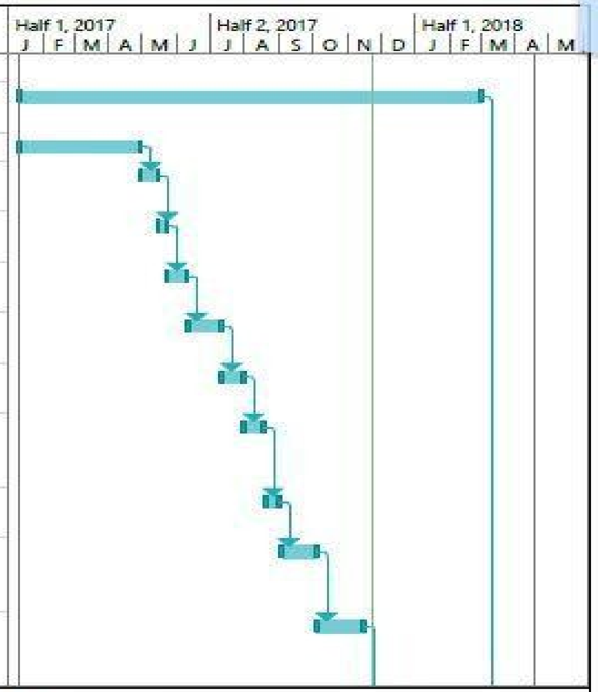
It was revealed from the literature reviews that biodiesel is consisting the almost similar properties to diesel fuel. Which results in operating engines using biodiesel directly without any modifications. But the main problem which initially causes obstruction in commercializing the biodiesel in engines as fuel is its higher viscosity results in less atomization, less evaporation and incomplete combustion of fuel. Hence from many research investigations, it was concluded that transesterification method has somehow managed to reduce the higher viscosity nature in biodiesels to a large extent to make biodiesels best alternative adaptable future fuel for DI CI engines. From the research conclusions, the most preferred biodiesel is B20 means in which biodiesel content is only 20% and the rest is diesel fuel concentration.

From the previous experimental results, it has been indicated that the emissions like CO, HC, Particulate matter has drastically reduced which results in favor of environment as a safety blanket. Similarly, from previous research data it has been concluded that if in India 5% of biodiesel is used as a blend in diesel, 4000 crore rupees can be saved per year results in bright scope for future purposes

CHAPTER 10

10.1 Proposed work plan with timelines (Part 1)

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
1							
2			Literature and Feasiblity Survey	296 days	Thu 1/12/17	Thu 3/1/18	
3			Problem Identification	78 days	Thu 1/12/17	Sun 4/30/17	
4			Seeds Identification: Edible/Non-edible	11 days	Mon 5/1/17	Mon 5/15/17	3
5			Selection of Seeds: Non Edible	6 days	Tue 5/16/17	Tue 5/23/17	4
6			Indentification of Non-Edible Seed: Argemone and Thumba	14 days	Wed 5/24/17	Sat 6/10/17	5
7			Procurement of Seeds: Geographical Identification	22 days	Mon 6/12/17	Tue 7/11/17	6
8			Properties Identification as a Fuel: To be Measured	14 days	Wed 7/12/17	Mon 7/31/17	7
9			Method Identification for Yielding of Biodiesel based on Literature Survey	14 days	Tue 8/1/17	Fri 8/18/17	8
10			Identification of Experimental Setup and Accessories	10 days	Mon 8/21/17	Fri 9/1/17	9
11			Yielding of Biodiesel: Argemone and Thumba (B100)	24 days	Mon 9/4/17	Thu 10/5/17	10
12			Measuring of Fuel Properties: Argemone and Thumba (B100)	30 days	Fri 10/6/17	Thu 11/16/17	11

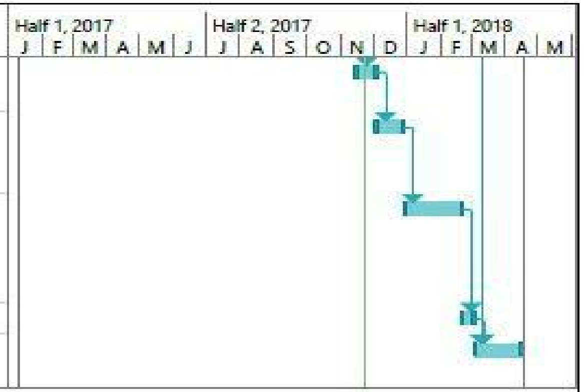


Project: Project1
Date: Fri 11/24/17

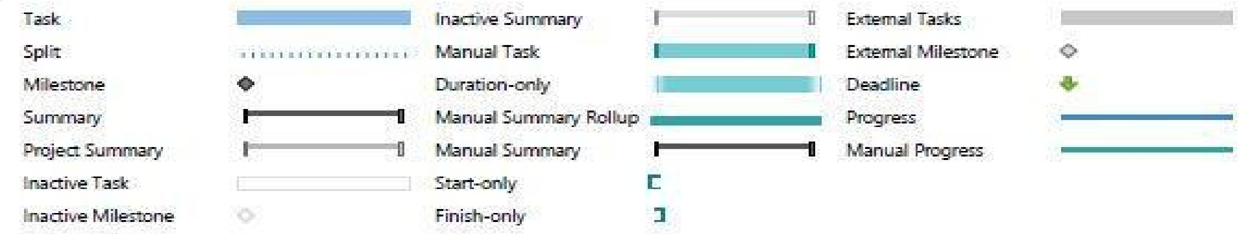
Task	Inactive Summary	External Tasks
Split	Manual Task	External Milestone
Milestone	Duration-only	Deadline
Summary	Manual Summary Rollup	Progress
Project Summary	Manual Summary	Manual Progress
Inactive Task	Start-only	
Inactive Milestone	Finish-only	

10.1 Proposed work plan timeline (Part 2)

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
13			Blend Preparation: B10, B20, B30 & B40	12 days	Fri 11/17/17	Mon 12/4/17	12
14			Measuring of Fuel Properties: Argemone and Thumba (B10,B20,B30 & B40)	19 days	Tue 12/5/17	Fri 12/29/17	13
15			Performance and Emission measurement of Dual Blended Fuel (B10, B20, B30 & B40) on Diesel Engine	37 days	Mon 1/1/18	Tue 2/20/18	14
16			Compilation of Result	9 days	Wed 2/21/18	Sat 3/3/18	15
17			Report Writing and Submission	32 days	Mon 3/5/18	Tue 4/17/18	2,16



Project: Project1
Date: Fri 11/24/17



CHAPTER 11

11.1 List of References

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