# Recycling of Used Vegetable Oils from Cafeteria's of Arba Minch City for Bio-Fuel Production

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**Abstract.**The initial survey was done at Arba Minch, Ethiopia. It is found that there are many cafeterias and restaurants around Arba Minch are using a considerable amount of vegetable oils for preparing varieties of food and snacks. After deep-frying of foods they are disposing the used cooking oil (UCO) down the sink and also discharged into the water bodies and become the cause of water living organisms. It is estimated that approximately around 430 liters of Used cooking oil (UCO) arise from catering annually in each cafeteria of Arba Minch town. In this concern, the raw UCO use to obtain more than 79% as bio feedstock for the production of biodiesel at the end of the process. An even enormous amount of collectible household cooking oil waste is also likely available. Hence, this research was focused on making a profit of community in addition to save the environment from the used cooking oil. The appropriateness of used cooking oil has been set up in this research. In this study, used cooking oil has been collected, purified, transesterified and properties of transestefied used cooking oil biodiesel (TUCO) were studied and it is evident that the properties obtained were nearer to the conventional existing diesel. The performance characteristics of a single-cylinder, four-stroke, direct injection diesel engine, fuelled with TUCO are analysed and compared to local diesel results. The research has been done at a constant speed of 3500 rpm, and then it was gradually loaded. Also, the experiments were conducted at different loads, by increasing torque, for compression ratios of 22:1 and injector pressure of 210 bar. Among the two samples (Diesel, TUCO tested), the best performance is achieved by biodiesel. Furthermore, the end values revealed that the test engine performance such as brake thermal efficiency, energy consumption, and fuel consumption is similar to diesel, when fuelled by transesterified used cooking oil reduction of power-output by 5.51% was noticed. The total fuel and specific fuel consumption also perceived to be an increased by 0.331% and 0.064%. Even though TUCO performance is reduced it may be improved by varying different engine parameters and by additives.

**Keywords:** Diesel, Performance, Transestefied Used cooking oil, Biodiesel, Engine.

## 1 Introduction

Most employed fuel for heavy-duty and light-duty engines are diesel. The requirement for source of energy is elevating everywhere in the world, specifically the need for petroleum based fuels. In the present situation ninety percentage of demand for the energy covered by conventional combustible fossil fuel, predominantly by products from petroleum, these fuels

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are neither in adequate quantity nor at affordable prices. In the subsequent years, exploring replaceable different fuels for engines have to be procured from indigenous sources favourably sources from renewable category. Vehicles operating with diesel fuel were becoming popular because of superior efficiency and inferior emission. Diesel engines are used in most of the transportations, diesel power plants, building constructions and most of industrial applications. Used cooking oil is also called as Waste edible oil (WEO). Oils used for the purpose of cooking food materials can't be reused for the food consumption again.

Scrapping of huge quantity of UCO has become a problematic issue with maximum of countries. UCO not to be scrapped into sewages or drainage. In day to day usage, this will restrict the flow and vermin problems. These causes watercourse and also arising issues for wildlife. From the selected countries around the world, around 15 million tons of used cooking oil has been generated.

In Ethiopia, a considerable number of hotels, samosa & chips shops, etc., disposes the used cooking oil in the drainage. Its effect the water, fauna, flora, and human also. Numerous complications will be created in the engine while using directly used cooking oil or vegetable oil.

Short term problems are:

- Starting engines during cold weather.
- Gumming of the filter.
- Knocking of the engine.

Long term problems are:

- Injector coking.
- Deposits of carbon on the piston and head of the engine.
- Significant rise in engine wear.
- Lubrication oil polymerization [1].

## 2. Different Method of using used cooking oil in engine

***Pre-heating the vegetable oil***

The viscosity of vegetable oil can be reduced by heating them before injection. By preheating to about 75ºC, the viscosity of vegetable oil nearly equal to the viscosity of diesel [2].This will enhance the spray & mixture attributes between fuel and air in the cylinder. Pre-heated vegetable oil results in enhanced performance attribute with a reduction in emission attribute [3].

***Dual Fuel Operation***

A prevailing diesel engine can be effortlessly altered to work in this mode. This engine can accept a wide range of fluids & gaseous fuel as the primary energy source. The dual-fuel engine can catalyze in good brake thermal efficiency& significant low smoke emission mainly at the elevated power output.

Alcohols, LPG, Hydrogen, etc., have been widely used as instructed fuels in the dual-fuel engine [4].

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***Emulsion***

The emulsion is attained by mingling two immiscible liquids by employing either an electrical or mechanical homogenizing machine. A surfactant accompanied to the blend reduces the oil & water surface tension, stimulates the surfaces & enhances the ostensible contact areas to make an emulsion. The selection of surfactant is made based on the basis of HLB (HydrophileLipophile Balance) values, not more than 7 in order to compose water in oil emulsions.

***Blends with diesel or alcohol***

The fusing of vegetable oils accompanied by diesel fuel would settle the hindrances of diesel engine proceeding with raw vegetable oils. Vegetable oil disintegrates well off in diesel fuel. The diesel engine would operate effectively on a fusion of vegetable oil and diesel fuel devoid of detriment to engine accessories for short-term functioning. To eliminate these obstacles is to diminish fuel viscosity and thus enhancing injection attributes.

***Transesterification of vegetable oil***

Transesterification is the mechanism of transforming the triglycerides of vegetable oil to these monoesters by treating them with alcohol in the presence of a catalyst such as KOH (Potassium Hydro oxide), NaOH (Sodium Hydro oxide), etc., to produce glycerol & fatty acids. This mixture of fatty esters produced by this reaction is referred to as biodiesel [5].

A research was therefore, attempted with the initiative of determining the maximal feasible substitution of diesel by using transesterified used cooking oil and to study the performance attributes of a constant speed C.I. engine operated with TUCO and Diesel. Since the transesterification technique was widely used for the formation of biodiesel, this process has been used in this research for obtaining renewable fuel.

## 3 Materials and methods

Usedcooking oil (UCO) was collected from the cafeterias located in Chamokebele, Arbaminch. The used oil specimen was obtained from the Oil fryer which was used for frying chips and farther food items. The temperature noticed around frying was in the limits of 130˚C - 170˚C. This temperature could be compared with the temperature around 140 - 180˚C for preparing French fries.

Fig.1 Cafeteria Owners receiving Green Bin from Research Team

The collected UCO was stored in a plastic container in the laboratory for further processing. These are the raw materials sources for the preparation of biodiesel. Also, these raw materials include triglycerides, free fatty acids, including other contaminants. Figure 1 shows the collection of used cooking oil from the cafeteria owner means of the green bin.

## 4. Production of biodiesel by transesterification

### *A. Filtering and Drying*

The used cooking oil wants to be filtered to eradicate any food leftover particles which could affect fuel production. This was done during the sample preparations. The filtration process has been done by sedimentation as shown in figure 2 and the Centrifugation process as shown in figure 3. The oil was dried as much as possible because water reduces the efficiency of transesterification. The filtered and purified used cooking oil is shown in figure 4.

Fig. 2 Sedimentation Process

Fig. 3 Centrifugation Process

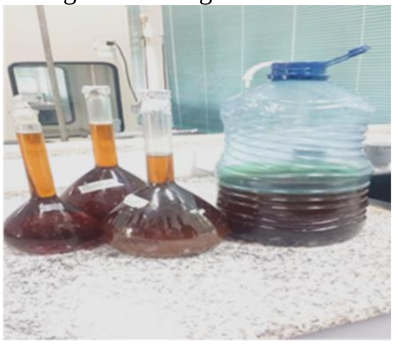

Fig. 4 Purified UCO

***Transesterification process***

The base-catalyzed transesterification method was adopted for the preparation of biodiesel. Accurately weighed volume (100ml) of the oil sample was poured in a 250ml three-necked round bottom flask (see Figure 5). The oil has been pre-heated to 50˚C by using a water bath with a temperature regulator. About 1.5g of catalyst potassium hydroxide (KOH) was dissolved in 20ml of methanol. The potassium methoxide solution has been appended to the pre-heated oil containing flask. The experimental setup was placed on a hot plate magnetic stirrer at 65˚C with a constant speed at 500 rpm. The corresponding alcohols-hydroxide solution with vegetable oil was heated about 2 hours to complete the transesterification. Afterwards, 50ml of water has been carefully checked and flowed genially on the produced specimen to refine it. The blend has been smoothly mixed to prevent foam production and allowed throughout the night for perfect settlement of two phases, specifically: water phase and biodiesel phase [6]. The biodiesel has been abstracted from glycerol by employing separating funnel. The resultant product has been taken into the separating funnel having biodiesel and glycerine. Beyond 24 hours, glycerin was observed and settles down at the bottom of the funnel and biodiesel settles on top of separating funnel. Glycerin was separated by opening the valve of the separating funnel as shown in Figure 6.

***Washing***

The produced methyl ester of biodiesel necessarily to be washed again to extract the remaining methanol (about 10th by volume) and soapy lay downs. The glycerol sort out as a segregated surface by settling. Potentially glycerol can be utilized by domestic soap-manufacturing companies. Charcoal filtration is used to remove the colour noticed by dyes from the used cooking oil. The separated biodiesel was obtained (shown in Figure 7) and it has been heated to 100˚C for 60 minutes to vaporize the residual water molecules on it.

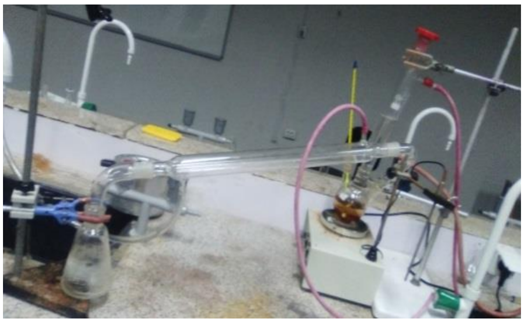

Fig.5 Experimental setup

Fig. 6 Biodiesel Separation

Fig. 7 Refined biodiesel

The percentile of the transesterified used cooking oil obtained was calculated by correlating the mass of layer of transesterified used cooking oil with the weight of UCO has been used.

$$\text{Biodiesel yield (\%)} = \frac{\text{Grams of methyl esters produced}}{\text{Grams of oil used in reaction}} \times 100$$

## 5. Physiochemical Description of UCO and TUCO

The physiochemical characteristics of UCO and TUCO were described according to ASTM D6751-02 [7].

### A. *Measurement of Moisture Content*

The samples of filtered UCO and transesterified used cooking oil (TUCO) (1g) weighed accurately and taken into pre-weighed clean dry crucible. The samples were placed at 105˚C in a hot air-oven for 2hrs and placed in desiccators; the weight of the samples was taken every 30 minutes until a constant weight was obtained. The outcome of individual try sample has been found and noticed. The amount of moisture on the samples was determined by using:

$$\text{Percentage moisture content} = \frac{W_i\text{-}W_f}{W_i} \text{ x } 100$$

Where,

$W_i$- initial weight of the sample before drying

$W_f$- final weight of the sample after drying

The primary raw materials were used for the production of TUCO via transesterification is UCO. The percent yield of UCO is about 90.24% of unfiltered UCO was recovered after the removal of food residues and sediments under the action of gravitational sedimentation and by chemical coagulation by using Al2SO4 (2%) as a coagulating agent. Also, there is no unreacted oil were observed on the TUCO, which was produced from UCO.

The results (see Table 1) were revealed that there is no water and sediments were found in TUCO, that were produced from UCO, even fewer amount of moisture (0.27% in UCO) was observed. A rotator evaporator has been employed to remove the water and leftover alcohol. The experiments were revealed that the whole eradication of water and non-reacted alcohol has been measured upon the observation of constant weight approached during the rotator evaporation. According to the ASTM standard value for water and the sediment is 0.5% by volume of the sample was recommended. Thus, the results shown that the TUCO produced from UCO were purified and refined well in this present study.

### B. *Measurement of Saponification Value (S.V), Acid Value (A.V), Iodine Value (I.V), Ester Value and Free Fatty Acid Content*

About 2g of an UCO and TUCO were added in to 250ml conical flask and 25ml of 0.5M ethanolic KOH, which is prepared by dissolving KOH pellet in 95% ethanol, was added to the samples. Similarly, the blank solution (all chemicals except samples) was prepared in another conical flask. Reflux condenser was attached to both sample and refluxed for an hour by constant stirring. After complete refluxing, 5 drops of phenolphthalein indicator was added, while it was hot; titrated against standard 0.5M HCl and the finishing point was noticed. The saponification value was determined using the following formula:

$$\text{Saponification value (mg KOH)} = \frac{56.1 \text{ x N x } (V_o\text{-}V_1)}{W}$$

Where,

N - Concentration of hydrochloric acid

$V_0$- Volume of HCl used for the blank

$V_1$- Volume of HCl used for the sample

W - Weight of sample (in g) taken

56.1 - molar mass of KOH

Accurately measured amount (2g) of UCO and TUCO samples were added into 250ml round bottom flask and the blend has been heated to $700^0$C for 3 minutes. Then, 25ml of 1:1

ratio of absolute ethanol and diethyl ether solution was added to the UCO under continuous stirring. Phenolphthalein indicator (5 drops) has been incremented to the each sample solution and titrated against standard 0.1M KOH to the end point, which is the appearance of faint pink color. Similarly, the blank solution was prepared and titrated against 0.1 M KOH to the finishing point. Acid values of the samples were calculated as:

$$\text{Acid value (mg KOH)}= \frac{56.1 \text{ x N x } (V_o\text{-}V_1)}{W}$$

Where,

N - Concentration of KOH;

$V_0$- Volume of HCl used for the blank

$V_1$- Volume of HCl used for the sample;

W - Weight of sample (in g) taken

56.1 - molar mass of KOH

About 0.25g of samples was taken in clean 250ml conical flask, 10ml of chloroform and 30ml Hanus iodine solution was introduced to it. The flask was securely closed and left for shaken, and then 100ml of distilled water was introduced. The blend has been titrated accompanied by the iodine solution opposed to 0.1 N sodium thiosulphate solutions until the yellow color originated. Later 2-3 drops of starch solution have been introduced. The titration was performed until the finish point has attained, while the volume of $Na_2S_2O_3$ was noted.

$$\text{Iodine value (mg KOH)}= \frac{12.69 \text{ x N x } (V_o\text{-}V_1)}{W}$$

Where,

N - Concentration of sodium thiosulphate

$V_o$ - Volume of sodium thiosulphate used for blank

$V_1$ - Volume of sodium thiosulphate used for sample

W - Mass of the sample

The transesterification process of glycerides with catalyst and alcohol has been much influenced by free fatty acid content. To find the free fatty acid value, 1g of individual sample has been diluted in a 23ml of neutral blend (same mass of diethyl ether and methanol). The obtained sample solution has been titrated with 0.1 M NaOH solution along a phenolphthalein indicator mixed in drops.The titration has been processed up to finish point has been attained. The final point has been noted as the pink color origination.

$$\text{Free Fatty Acid (\%)}= \frac{\text{TV x 0.0282 x 100}}{\text{weight of sample}}$$

Where,

TV is the titre value

0.0282 is the constant (weight of oleic acid neutralized by 1mg of KOH)

The ester value of the oil samples was calculated as the variation within the saponification value and the acid value. Therefore,

Ester value = Saponification value – Acid value

The saponification value of UCO is observed as 133.24 mg/g while that of its TUCO is 56.1 mg/g respectively. This shows that the triglycerides of UCO have the greater molecular weight of fatty acids (saturated and unsaturated) and the results of this present study are well agreed and a similar trend was observed in reported literature. This result obtained compares favourably with the saponification value of palm oil (187-205), olive oil (185-187), and soy oil (187-193). Saponification is highly used in checking adulteration.

Edible oils iodine value has been observed lesser than 100mgI2. In common, higher the iodine value, the greater degree of unsaturation and more it prone to oxidative rancidity.

However TUCO is 120.53 mgI2, which one is comparatively more, as per Europe's EN14214 specifications of iodine value, which shows the UCO are the worthy source material for the manufacturing of alternative fuel. This justifies the highest iodine value shows the higher numbers of unsaturated double bonds occur in the molecule structure and lower the viscosity [8].

The total acid number for transesterified vegetable oil has been given as 0.8mgKOH/g by ASTM standards. The whole number of potassium hydroxide required for neutralizing the free fatty acid available in vegetable oil/transetereified vegetable oil samples is denoted as acid value. The acid value of ethanol assisted transesterified canola oil, linseed oil, rapeseed oil and sunflower oil were 0.869, 0.884, 0.873 and 0.876 mg KOH/g consecutively as reported by literature [9]. The experimental acid value of TUCO was identified as 0.50mg KOH/g UCO and 0.42 mg KOH/g. These acid values can be further enhanced by managing the Transesterificaton process. The acid value with higher number shows the poor or unrefined source of vegetable oil, these higher values leads to filter clogging and damaging of rubber parts..

The major measure of the biodiesel property was the fatty acid content. Matching samples have been employed for determining the fatty acid content of vegetable oil/transetereified vegetable oil. The results were presented in Table 1 and it was estimated about 1.88% and 1.128% in UCO and TUCO respectively. The UCO and TUCO contain more FFA, among 60% fatty acid is from monounsaturated (C18:1). Poly unsaturated fatty acids identified to be 26% (C18:2 & C18:3), only roughly 8 % fatty acids were saturated. As per the reported literatures [10], the prime saturated fatty acids are Palmitic acid and stearic acid. The viscosity of vegetable oil/transetereified vegetable oil is identified to be depending on the type and amount of fatty acid content. Thus, implies that TUCO derived from UCO of the study was observed at viscosity of 5.23mm$^2$/sec.

The alkaline catalyst used for transesterification of raw materials with free fatty acid content has a greater impact on the yield and the quality of the resultant product. The extraction of biodiesel from the total products will be more complex when the free fatty acid content of the feedstock is more than 3%. i.e. the viscosity of the biodiesel will be increased by soap formation [11].The free fatty acid value was 1.13% for TUCO, which comes within the allowable range for transesterification with alkaline catalyst. The result was obtained from 1.88% of UCO; this implies that the oil converted into methyl fatty esters.

***Determination of Specific Gravity and Viscosity***

About 5ml capacity of density bottle was pre-weighed ($W_0$). It was filled with UCO/TUCO, then inserted stopper and weighed again (taken as $W_1$). The UCO/TUCO was substituted with water after washing and drying the bottle and weight of the density bottle was measured again weighed (taken as $W_2$). The specific gravity of the samples was calculated as:

$$\text{Specific gravity, S.G. (\%)} = \frac{W_1 - W_o}{W_2 - W_o}$$

$$= \frac{\text{Mass of the sample}}{\text{Mass of an equal volume of water}}$$

Viscosity is an amount of the obstruction of a fluid being crippled by anyone of shear stress or tensile stress. Exactly taken 15ml of water has been drawn by suction pipe until it crosses the top mark of the viscometer, and the time taken by the water to flow from top-mark to low-mark was noticed with the use of a stopwatch. Then 15ml of test samples were taken in a viscometer. It has been drawn by suction pipe till the sample crosses the top mark of the viscometer. Now, the time needed by the samples to flow from top-mark to low- mark was noted [12]. Relative viscosity of the sample found by the equation as:

$$\text{Relative viscosity}= \frac{T_o}{T_w}$$

Where,

$T_o$ - Time taken for oil/ UCO/TUCO to travel from top mark to low mark

$T_w$ - Time taken for water to travel from top mark to low mark

The results in Table 1 show that the specific gravity was reduced from 0.9258 to 0.91 on UCO after transesterification and it is coming under acceptable limit and also well agreed with ASTM standard and other reported literatures. The greater viscosity is the utmost problem restricting the access of vegetable oils and animal fats directly into diesel engines. The viscosity of the used cooking oil was measured by use of a falling fluid viscometer. The results observed that the average viscosity of UCO were measured (at room temperature) to be 65 $mm^2$/sec respectively. The viscosity of the TUCO was obtained from UCO were reported as 5.23 $mm^2$/sec respectively, that value is within acceptable limits by ASTM. The ASTM limit for biodiesel viscosity was reported 1.9-6.0 $mm^2$/sec at 30oC

***Measurement of Higher Heating Value and Cetane Number***

Higher heating value (energy content per unit quantity) of UCO/TUCO was estimated from their saponification value and iodine value using the following correlation:

$$HHV = 49.43 - [0.041(S.V) + 0.015(I.V)]$$

Cetane number is used to determine the ignition delay after injection of fuel. In this present study, the cetane number of UCO/TUCO was estimated based on its saponification value and iodine value using the following correlation [13]:

$$\text{Cetane number (C.N.)}=46.3+\frac{5458}{S.V} - I.V.$$

The ignition standard of the diesel fuel is measured by certain numbers. Enhanced cetane number eases the starting of the engine. Cetane number is the percentage of available hexadecane by volume in a cetane and 1-methylnapthalene (combustible mixture), which property of ignition equals of the fuel being tested. The cetane number of the TUCO was identified to be 87, which is more than that of local diesel of 48 - 65 as in reported literature. The increased cetane number reduces the ignition delay period, thus facilitates smoother combustion and efficient ignition. Biodiesel has an increased cetane number than the local diesel by their oxygen content by nature. The performance and emission properties of the engine are enhanced by a superior cetane number. Since the biodiesel produced have a higher cetane number, it possess a positive credit.

The thermal energy produced per unit amount of fuel after complete burning and retained to initial temperature is called as Heating value of a particular fuel. It is basically a resource to identify the energy content of a particular fuel. ASTM standard methods are used to study this property by using the Iodine and saponification value of the particular fuel.

The higher heating values (HHVs) of studied oil 43.19 MJ/kg for UCO are good agreement with literature and TUCO are relatively high (see Table 1). The HHVs of studied biodiesel's 48.94 MJ/kg for TUCO is moderately inferior compared to diesel (49.65 MJ/kg). The combustion process has been enhanced by content of oxygen available in biodiesel, similarly it reduces the oxidation potential. Combustion efficiency of the engine is increased by the homogeneity of oxygen content in the biofuel. HHV of the biodiesel can be estimated depending on the physical properties i.e flash point, boiling range, viscosity, density, cloud point, pour point, boiling range, freezing point and refractive index.

Table 1. Physicochemical characterization of UCO and TUCO

| **Sl.No** | **Properties** | **Estimated values** | |
|---|---|---|---|
| | | **UCO** | **TUCO** |

| | | | |
|---|---|---|---|
| 1 | Yield of oil (%) | 90.24 | 78.56 |
| 2 | Moisture content (% wt.) | 0.27 | 0.18 |
| 3 | Specific gravity | 0.9528 | 0.91 |
| 4 | Relative Viscosity ($mm^2$/sec) | 65 | 5.23 |
| 5 | Saponification value(mg/g) | 56.1 | 133.237 |
| 6 | Iodine value(mg I2/g) | 51.74 | 120.53 |
| 7 | Acid value(mg/KOH) | 0.50 | 0.42 |
| 8 | Free fatty acid (%) | 1.88 | 1.128 |
| 9 | Cetane Index | 137.5 | 87 |
| 10 | High Heating Value (MJ/kJ) | 43.19 | 48.94 |

## 6. EXPERIMENTAL SETUP

The diesel engine used for this experiment. Diesel engine used is a mono cylinder, 4 stroke, air cooled, Constant Speed, Direct Injection, coupled with a dynamometer. The digital RPM indicator is employed to study the speed of the Engine. The burette (Glass tube) is used to evaluate the flow rate of fuel used by the running condition and controlled with the help of three way valve system. The stop watch is used to measure the quantity of fuel flow from a burette.

### *A. Experiment Procedure*

The block illustration of the test setup has been given in figure 8. Test engine used in the experiment is a Gunt CT 110 4-stroke (bio) diesel engine as shown in figure 9. It is air-cooled mono cylinder 4-stroke Diesel Engine. A mono cylinder, air cooled, 4 stroke direct injection, compression ignition engine developing 5.5 kW at 3500 rpm with a compression ratio of 22:1, developing 5.5 kW at 3500 rpm was used for the present study. Different load experiments are done for no load, 5, 10, 15, and 20 kg power output at a stable speed of 3500 rpm and 210 bars fuel injection pressure.

The standard injection timing of the engine is $27^0$bTDC. The governor has been employed to keep speed constant during variable load condition. This made possible by governor by controlling the flow of fuel during the change of load. The engine used has an open type combustion chamber with push rod controlled overhead type valves. The time utilized for 10cc consumption of fuel was measured by employing stop watch for fuel and at different loads. The performance characteristics of the engine are measured by brake thermal efficiency, specific energy consumption, and total fuel consumption. The performance characteristics of biodiesel blend are set against with the results of the baseline diesel engine.

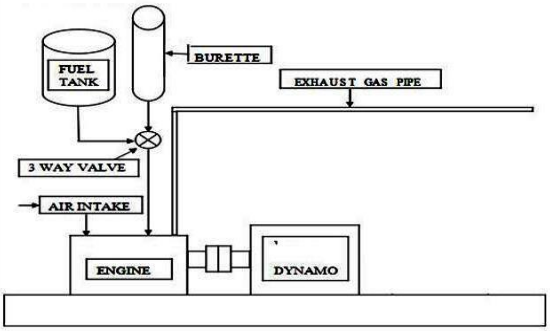

Fig. 8 Experimental Setup

Fig. 9 Test Engine setup

## 7. PERFORMANCE CHARACTERISTICS

### *A. Brake Thermal Efficiency for Tuco and Diesel*

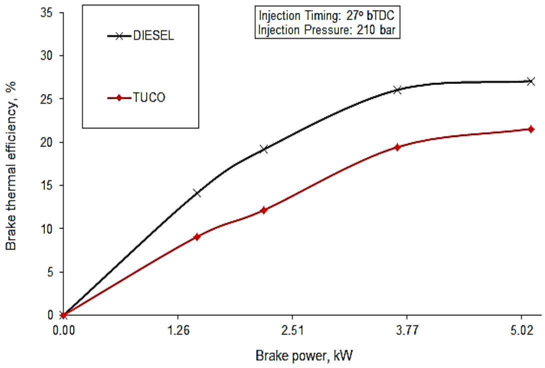

Fig. 10 Variations of Brake Thermal Efficiency with respect to brake power

Brake thermal efficiency shows the achievement as energy source of the distinct fuel. Brake thermal efficiency is simply the opposite of the specific fuel consumption [14]. Higher loads show the higher brake thermal efficiency. The performance of the specific fuel will be evaluated by brake thermal efficiency. Transesterified used cooking oil has a lesser brake thermal efficiency than the local diesel efficiency. Transesterified used cooking oil shown 5.51% lesser brake thermal efficiency compared to the diesel efficiency as shown in figure 10. The reduction of efficiency in TUCO is due to lesser calorific value and the marginal viscosity increase compared to diesel. Because of these properties it exhibits inferior atomization of the fuel, lesser heat release rate and combustion incompleteness.

### *Total Fuel Consumption for TUCO and Diesel*

It is observed that the total fuel consumption of the diesel is lesser, while it is higher for transesterified used cooking oil [15]. This is because of the diesel have better combustion compare to transesterified used cooking oil and the heating value of the diesel is higher than the transesterified used cooking oil. Due to this reason the total fuel consumption for diesel is lesser than the Transesterified used cooking oil. Total fuel consumption for transesterified used cooking oil is 0.331% higher compared to the diesel as shown in figure 11.

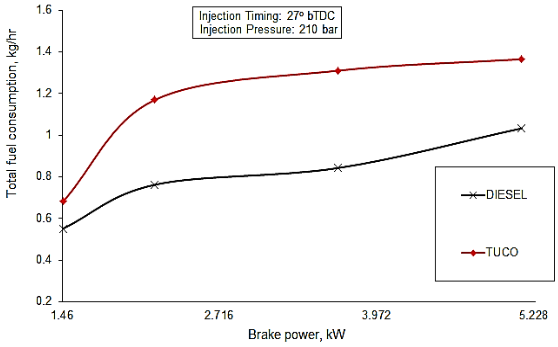

Fig. 11 Variations of Total Fuel Consumption with respect to brake power

### *Brake Power with Respect to Specific Fuel Consumption for TUCO and Diesel*

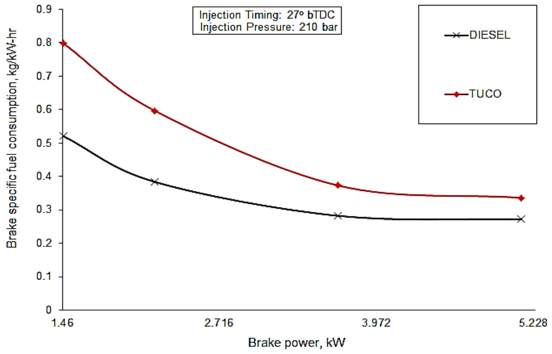

Fig. 12 Variations of Specific Fuel Consumption with respect to brake power

Specific fuel consumption is a vital fact to be examined. It is observed that the specific fuel consumption of the diesel is higher for transesterified used cooking oil [16]. Specific fuel consumption for transesterified used cooking is 0.064% higher compared to the diesel. The high viscosity of the transesterified used cooking leads to the inferior atomization, thus the ignition delay period has been increased. These reasons lead to the increase in specific fuel consumption as shown in figure 12.

## 8. EXPERIMENTAL SETUP

The subsequent conclusions are formed from the current investigation of performance characteristic of diesel – transesterified used cooking oil. Physiochemical properties obtained from transesterified used cooking oil were closer to diesel. Diesel engine would be operated using transesterified used cooking oil without any modification. Transesterified used cooking oil shown 5.51% lesser brake thermal efficiency compared to the local diesel efficiency. Specific fuel consumption found to be 0.064% more for transesterified used cooking oil compared to local diesel. Total fuel consumption found to be 0.331 % more for transesterified used cooking oil compared to local diesel. Using of transesterified used cooking oil reduced engine performance, due to the decrease in the calorific value and the higher viscosity. Considering above reasons, used cooking oil has a lesser performance than the diesel. But the source of fuel is renewable and locally available; it can be justified as an alternate source of energy.

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