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Fuel Properties of used Cooking Oil extracted from different Edible Oil Seeds

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Abstract

The waste or left over cooking oil used as a biodiesel is gaining momentum. Factors like the mass consumption of cooking oil and thereafter huge quantities of used cooking oil(UCO) as a waste, disposal problems, price hike and depletion of conventional resources, and economical viability of UCO has led to studies in this direction. Cooking oils are extracted from different edible oil seeds viz., Sunflower, Groundnut, Palm, Mustard, etc. though all vegetable oils consists of triglycerides which contains Hydro carbon along with fatty acids, the quantity of free fatty acids(FFA) may be same or different. Hence, investigation to identify the FFA of oil samples extracted from above said Oil seeds and further determine the Fuel Properties viz., Viscosity, Calorific value, etc was carried out. The results obtained show Mustard biodiesel had a higher viscosity of 32cSt and palm biodiesel shows least viscosity of 6cSt at 40^0C in comparison to diesel at 40^oC which is approximately 5cSt. The calorific value of mustard biodiesel has slightly better calorific value in comparison to the other three biodiesel samples.

Keywords: *Biodiesel, Free fatty acids (FFA) Trans-esterification, Viscosity, Calorific value*

1. Introduction

With rapid modernization and industrialization, consumption of fuel has increased many folds which has led to increase in demand and cost of conventional fuels. Since convention fuels offer ideal characteristics viz., good heat value, ideal viscosity and low density which has worked in its favor as an ideal fuel for IC engine. Due to scarcity of conventional fuel, the use of Biofuels as alternative fuels has gained momentum. Waste cooking oil left out after frying can be readily converted into biodiesel which to an extent can reduce the dependency on conventional fuels. The advantages of using edible oil includes renewable, clean resource and economical in comparison to crude oil. Cooking oil discarded after cooking can be processed and converted to fuel by chemical and thermal process like Esterification / Trans-esterification, Distillation etc. Further as Edible Oils are extracted from variety of seeds namely Ground-nut, mustard, sun-flower, Palm-Oil etc.

Enormous amount of research has been carried out on used cooking oil as biodiesel as an alternative to conventional diesel.Kao-Chia Ho [1] in their investigation on waste cooking oil (WCO) as feed stock for biodiesel production by method of trans-esterification adopted a two step procedure in order to avoid reaction between free fatty acids (FFA) and NaOH to form soap resulting in a decrease in biodiesel conversion efficiency. A two-step process, consisting of esterification with acid catalyst and follow-up Trans-esterification with base catalyst was developed. This two-step process could lower the content of FFAs in waste cooking oil in the first step and also improve conversion of Trans-esterification in the second step. However they said procedure is only done if the FFA is beyond 3%. Sethur et al., [2] studied the effect of Butyrate hydroxytoluene(BHT) and n-butanol as additives in waste cooking oil (WCO) biodiesel, on the engine performance and exhaust emissions. Diesel in different proportions to form different blends such as B20 (20% WCOME and 80% 132 diesel), B30 (30% WCOME and 70% diesel), B40 (40% WCOME and 60% diesel) and B100 133 (100% WCOME) were used for testing. The waste cooking oil bio-diesel/ diesel blends with additives (B0, B20, B30, B40, B100, B30+BHT and B30+n-butanol) were tested in the single cylinder four stroke natural aspirated direct injection diesel engine runs at 1500rpm for different loads. The comparative studies were carried out to estimate the performance, combustion and emission characteristics of the above blends with reference to diesel. The authors concluded that performances of B30 with additives are satisfactory among other biodiesel blends. B30+n-butanol blend have less CO emission than diesel and More NOx emission was observed for B30+n-butanol blend. Shitu Abubakar et al., [3], investigated the production of biodiesel produced from used cooking groundnut oils using alkali trans-esterification reaction in the presence of Methyl Esters. The fuel properties of the fuel were determined and confirmed as per the ASTM standards. The biodiesel was tested on 165F- Horizontal Single Cylinder Direct Injection Diesel Engine and engine performance parameters were determined, also the emissions were analyzed. In their results they concluded that, the kinematic viscosity of all the biodiesels under consideration fall within the ASTM D455 standards ranging from 2.2cST to 2.5cST. Density of 0.88(gms/cc) to 0.875(gms/cc) well within the limits as per the ASTM standards of 0.9.The flash point 58.5^{o}C (ASTM= 130^{o}C) & Cetane number of 47.9 (ASTM 90.6). Tomesh Kumar Sahu [4] investigated fuel properties like density, kinematic viscosity, calorific value, oxidation stability, cold weather properties (CFPP, CF, and PP), and flash point temperature for three different types of biodiesels viz., Jatropha Biodiesel (JBD), used cooking oil biodiesel(UCO) and ethanol. The results are compared with pure form of diesel. They concluded that the densities of JBD (863 kg/m3) and UCO bio diesel (892.5 kg/m^3) are higher than the density of diesel (822 kg/m^3) while ethanol has lower density (795 kg/m^3) among all the tested fuels. The calorific values of biodiesel and ethanol are found to be lower when compared to that of mineral diesel. The authors finally concluded that biodiesel (pure and blended forms) may be suitable to use in CI engines when it comes to flash point, calorific value and PP, While ethanol (pure and blended forms) may be suitable for CI engines in terms of viscosity, density and CP. Atanu Kumar Paul et al [5] conducted investigation on, physio chemical properties and rheological behavior of Used cooking oil (UCO), castor oil, (CO), rubber seed oil (RSO) and their methyl esters (ME), as well as ME blends (5, 10 and 15 vol%) with diesel. The Rheological properties of samples were measured within a temperature range of 25–80 C and shear rate of 5–300 s1. Also, rheological behavior of WCO, CO and RSO based methyl esters (WCOME, COME, and ROSME) and its blends (5, 10, and 15 vol %) with diesel fuel were also studied. The samples were cheeked if they behavior as per Newton's law of viscosity. All the samples were found to be Newtonian within the temperature range of 25 to 80 degree C, however a slight deviation was, noticed at higher temperatures. The results of their investigation revealed that Physio chemical properties and rheological behavior of the three non-edible vegetable oils (WCO, CO and RSO), methyl esters (WCOME, COME and RSOME) and their blends with diesel, viz dynamic viscosity of CO was found to be higher compared to the other two oils (RSO and WCO). Higher content of ricinoleic fatty acid and ester in CO and COME were responsible for high viscosity values. Kinematic viscosity values of both RSOME (3.81 mm^2/s) and WCOME (3.36 mm^2/s) were found to be lower than that of most methyl esters (4 mm^2/s).

In the present work, an investigation is carried out to compare the fuel characteristics of the

UCO extracted from the aforementioned edible oil seeds.

2. Methodology

The step by step procedure adopted in the identification and analysis of thermal properties of used cooking oil extracted from edible oil seeds in the present investigation is shown in figure 1.

2.1 Free Fatty acid test

The purpose of this test is to determine the amount of Free Fatty Acids (FFA) present in the Used cooking oil, based on this one can decide if the conversion of UCO to Biodiesel requires Esterification process.

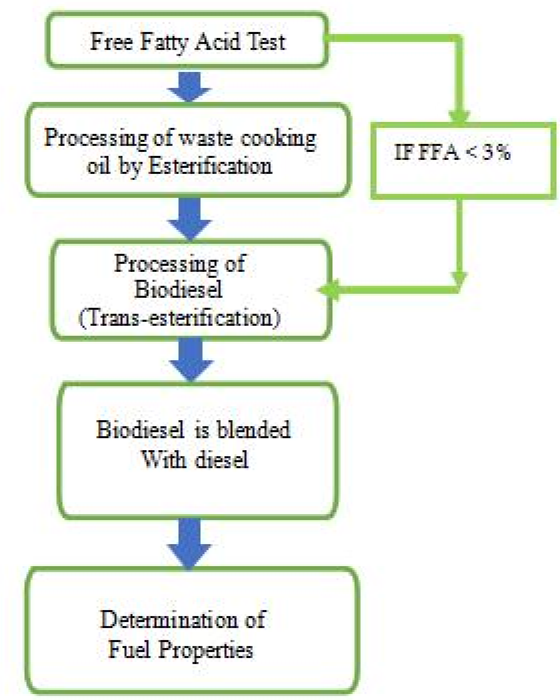

Figure 1: Block diagram of proposed methodology

In the present investigation the sample of oil collected after thorough filtration was subjected to the FFA test. The method to determine FFA is titration, it involves 10gms of sample mixed with 50ml of methanol and the mixture is heated and allowed to cool, after cooling down phenolphthalein indicator is added to the mixture then it is titrated against 0.1N Sodium Hydroxide until the mixture turns into pink color. The percentage of FFA is determined by using Equation 1

$$\%FFA = \frac{28.2 \times N \times BR}{W} \times 100 \qquad (1)$$

Where, BR is the Burret reading and W is the weight of the oil.

2.2. Trans-esterification Process

Since all the samples collected had a FFA of less than 2%, therefore the samples were subjected to Trans-esterification process to produce biodiesel.
Trans-esterification process is a catalyzed chemical reaction involving vegetable oil and alcohol to yield fatty acid alkyl esters (biodiesel) and glycerol. The block diagram shown in figure 2 is the step wise procedure for obtaining biodiesel from UCO.

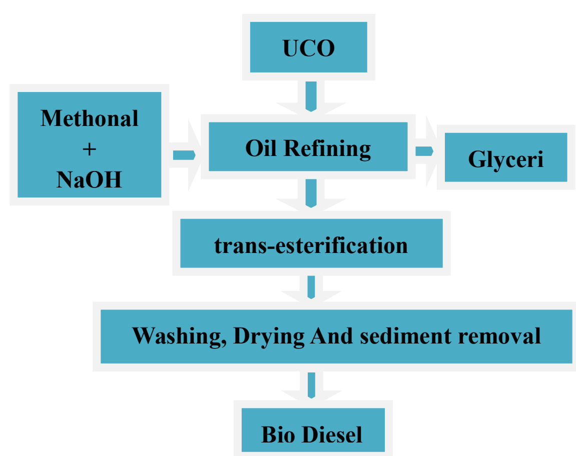

Figure 2: Flow chart- Conversion of UCO to Bio diesel

As shown in the flow chart the steps involved in conversion of UCO to biodiesel is per the standard procedures commonly followed. The reaction requires a catalyst, usually a strong base, such as sodium and potassium hydroxide or sodium methyl acetate.

Steps involved are

1. Mixing of catalyst with alcohol to produce alkoxide solution.

2. Mixture is charged into a closed vessel and oil is added.
3. Glycerol and biodiesel can be separated by gravity using settling vessel.
4. Removal of excess alcohol by distillation
5. Washing of biodiesel by hot water (40-50^{O}C) to remove NaOH, methanol and glycerol. Then it is heated to 110^{o}C to remove trace of water.

Trans-esterification setup is shown in figure 3.

Figure 3: Trans-esterification Setup & Settling Vessel

The bio diesel samples collected after processing from UCO to Biodiesel are shown in figure 4.

Figure 4: Biodiesel Samples (Sun Flower, Ground nut, Palm, Mustard)

2.3 Fuel Properties

Tests are conducted to determine the fuel properties of the above said biodiesel samples in pure form & as a blend with conventional diesel and a comparative are made.

2.3.1 Viscosity

Viscosity is the property of fluid which defines the interaction between the moving particles of the fluid. It is the measure of resistance to the flow of fluids. The viscous force is due to the inter molecular forces acting in the fluid. The flow or rate of deformation of fluids under shear stress is different for different fluids due to the difference in viscosity. Fluids with high viscosity deform slowly.

Dynamic viscosity is expressed as the ratio of shear stress to shear strain. The unit of measurement is Pa s. usually; it is measured in centipoise (cP). Kinematic viscosity is expressed as the ratio of fluid dynamic viscosity to its density. The unit of measurement is m^2s^{-1}. Kinematic viscosity is determined as per ASTM D445 by conducting an experiment using Redwood viscometer, the experiment was conducted in four trials by heating the biodiesel samples to temperatures of 29^{o}C, 40^{o}C, 80^{o}C, 100^{o}C.

The Kinematic viscosity is determined using Equation 2.

$$\nu = 0.26 \times t - \frac{179}{t} \qquad (2)$$

Where, ν is the kinematic viscosity in centistokes and 't' is the time taken to collect 50 ml of oil at a given temperature.

2.3.2. Density

Density is a very common and important property of matter for a liquid, density is defined a s the mass contained in a unit volume. The more precise name for density is volumetric mass density. .Mathematically, density (ρ) is defined as the ratio between the mass (m) and the volume (V) of a substance/body. Density plays a vital role in deciding the fuel properties.

2.3.3 Viscosity Index (VI)

Viscosity Index is a parameter which gives an idea about the variation of viscosity with variation in temperature, higher the variation lower is the value of VI and Vice Versa. The value of VI is determined from Equation 3.

$$VI = \frac{H - U}{H - L} \qquad (3)$$

Where, H is value of viscosity in Centistokes of oils having Viscosity Index of 100, while L is Viscosity of Oils in Centistokes having VI of Zero. U is Viscosity of the test sample in Centistokes. All the samples measuring 50 ml are heated to a temperature of 40^oC and 100^oC) and collected using a Saybolt Viscometer, and the time taken measured in seconds.

2.3.4 Calorific Value (CV)

Calorific value also known as heating value is amount of heat liberated by a unit mass fuel when it completely undergoes combustion. Heating values can classified as higher heating value and lower heating value. Bomb calorimeter (Figure 5) is used to measure the calorific value.

Figure 5: Bomb's Calorimeter

Equation 4 is used to determine the calorific Value.

$$CV = \frac{T \times W - (CV_t + CV_w)}{M} \qquad (4)$$

Where, T-Max temperature reached during combustion.(^oC)
W-Water equivalent (2325 cal/^oC)
CV_t-Calorific value of the wire (9.32cal/^oC)
CW_t-Calorific value of ignition thread (21cal/^oC) and M-mass of the fuel in gms

3. Experimental Results and Discussions

3.1 Viscosity

Kinematic Viscosity and density determined for different types of Oils considered are presented in tables 1 to 5.

Table 1: Kinematic Viscosity and density of Sunflower Biodiesel at varying temperatures

Sl. No	Temperature ^oC	Time (sec)	Density (gms/cc)	Kinematic viscosity (cSt)
1	29	86	0.892	20.279
2	40	57	0.880	11.680
3	80	36	0.842	4.388
4	100	34	0.840	3.57

Table 2: Kinematic Viscosity and density of Ground Nut Biodiesel at varying temperatures.

Sl. No	Temperature ^oC	Time (sec)	Density (gms/cc)	Kinematic viscosity (cSt)
1	29	56	0.87	11.364
2	40	41	0.86	6.294
3	80	32	0.84	2.726

Table 3: Kinematic Viscosity and density of Palm Biodiesel at varying temperatures

Sl. No	Temperature ^oC	Time (sec)	Density (gms/cc)	Kinematic viscosity (cSt)
1	29	45	0.864	7.722
2	40	40	0.851	5.925
3	80	30	0.830	1.833
4	100	29	0.79	1.8

Table 4: Kinematic Viscosity of Mustard Biodiesel at varying temperatures

Sl. No	Temperature °C	Time (sec)	Density (gms/cc)	Kinematic viscosity (cSt)
1	29	206	0.889	52.691
2	40	127	0.876	31.611
3	80	53	0.856	10.403
4	100	45	0.84	7.72

The variation of kinematic viscosity with respect to temperature for different types of oils is shown in figure 6.

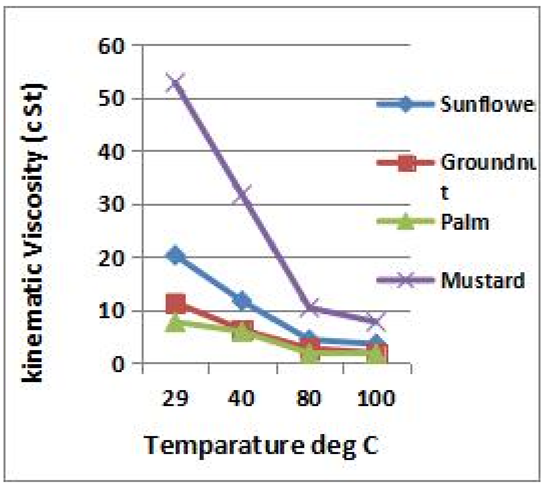

Figure 6: Kinematic Viscosity Versus Temperature

The results presented in tables 1-4 reveal that the kinematic viscosity of UCO from Palm and Groundnut at 40° are within the desirable range, while the kinematic viscosity of UCO from Sunflower and Mustard oils at 40°C are 11.6cSt and 31.611cSt respectively, which are on the higher side.

At temperatures near to 80°C, the viscosity is very low, which means biodiesel when used in diesel engine either in pure form or Blended form can be better atomized when preheated from room temperature to about 80°C before injecting it into engine cylinder. This would help in better mixing and also better performance of fuel injector.

3.2 Viscosity Index

Viscosity Index measured as per ASTMD2270 shown in table 5 is on higher side, which means variation in viscosity with temperature is low unlike say lubricating oils.

Table 5: Viscosity Index of UCO

Name of UCO Sample	Viscosity Index
Sunflower	212
Groundnut	145
Palm	144
Mustard	287

3.3 Calorific Value

Higher Calorific Values of Unblended biodiesel & blended biodiesel in the ratio of (9:1 & 8:2) are determined using Bomb calorimeter and calculated using Equation (4). The values are presented in tables 6-9.

Table 6: Calorific Value of Biodiesel (Blended and unblended)

S. no	Sun flower oil	Calorific Value(kJ/kg)
1	Unblended	39103.79
2	90% Diesel+10% Bio diesel	43879.21
3	70% Diesel+30% Bio diesel	41383.80

Table 7: Calorific Value of Biodiesel (Blended and unblended)

S. no	Ground Oil	Calorific Value(kJ/kg)
1	Unblended	37650.22
2	90% Diesel+10% Bio diesel	42445.85
3	70% Diesel+30% Bio diesel	40464.07

Table 8: Calorific Value of Biodiesel (Blended and unblended)

S. no	Palm Oil	Calorific Value(kJ/kg)
1	Unblended	36536.85
2	90% Diesel+10% Bio diesel	41495. 74
3	70% Diesel+30% Bio diesel	38961.33

Table 9: Calorific Value of Biodiesel (Blended and unblended)

S. no	Mustard Oil	Calorific Value(kJ/kg)
1	Unblended	39506.57
2	90% Diesel+10% Bio diesel	42969.18
3	70% Diesel+30% Bio diesel	41064.64

The results presented in tables 6 to 9, in unblended form, the Calorific values of all the biodiesel samples are lower when compared to pure diesel, while among all the biodiesel, mustard biodiesel has slightly higher calorific value, while Palm biodiesel has the least calorific value.

In case of Blended UCO B10 (10% UCO with 90% diesel), & B30 (30% UCO with 70% diesel) similar trends were seen. The overall reduction value between B10 & B30 of all UCO samples is by 4% to 6% and that between B10 & unblended is between 12% to 10% & between B30 & B100 (unblended) is between 6% to 4%.

Figure 7 shows the comparison between the calorific values of various bio diesel samples.

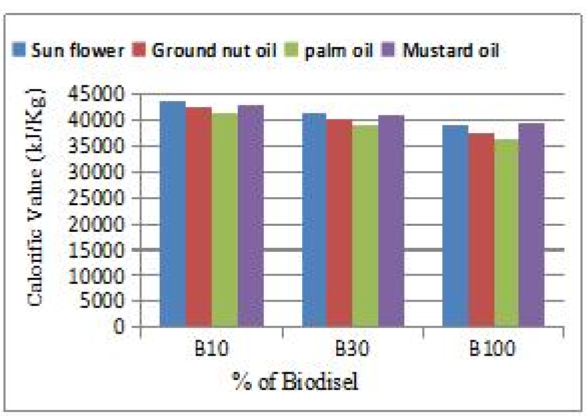

Figure 7: Comparison of Calorific Values

4. Conclusions

Cooking oils are extracted from variety of edible oil seeds, an interest in this regard to determine and compare for any variations in their characteristics as a fuel. In this direction samples of sunflower, groundnut, palm & mustard UCO were collected and a FFA test was conducted to check for the percentage of Free fatty acids in the samples. The test results showed that all the samples had FFA below 2% and hence the samples were subjected to Trans-esterification process to produce biodiesel. Viscosity, VI & Calorific Values of all the samples were determined, the results obtained show viscosity of all the UCO Biodiesel was within the standard limits at 40^{o}C (ASTMD2270), also the VI for all types of samples were higher which means not much variations in Viscosity with change in temperature. The Higher calorific values of all the Samples in Pure form B100 (Unblended with diesel) were within range of 45MJ/kg to 40MJ/kg as per ASTMD6751 (6).

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