

# Evaluation of Fuel (Biodiesel) Quality Parameters of the Seed Oil of Sweet Melon (*Cucumis Melo*)

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**Abstract** – Oil was extracted from the seeds of Sweet melon (*Cucumis melo*) using n-Hexane as a solvent. The physico-chemical properties of *Cucumis melo* seed oil (CMSO) such as specific gravity, viscosity, moisture content, refractive index, density, acid value, saponification value, iodine value, and peroxide values were determined and the results all fall within the recommended ranges as stated by biodiesel standard quality control organizations. Base-catalyzed Transesterification of (CMSO) was carried out at a methanol/oil ratio of 5:1 at 50°C producing biodiesel, a fuel comprising mono-alkyl esters of long chain fatty acid derived from vegetable oil or animal fat. The effect of potassium hydroxide (KOH) and sodium hydroxide (NaOH) catalyst were also investigated. The reason of the Transesterification process is to lower the viscosity. Fuel quality parameters like density, viscosity, cloud point, flash point, pour point, acid value, cetane number, higher heating values were also within the recommended range. The results of the effects of the two catalysts on the yield of biodiesel showed that KOH catalyst gave a higher yield of biodiesel compared to the NaOH catalyst. The biodiesel yields for KOH catalyzed process was 64%, while that for NaOH catalyzed was 46%. The fuel properties of CMSO methyl esters were similar to those of Soya bean and *pentaclathra macrophylla* biodiesel. Therefore the refined, chemically processed and degummed CMSO can be used to run compression ignition on engines for longer duration since the major problems of chocking with unmodified vegetable oil has been overcome.

**Keywords** – Sweet Melon, Properties, Biodegradable, Engine, Renewable Energy, Substitute, Vegetable Oil.

**Abbreviations** – ASTM, American Society for Testing and Material; DIN, German Standard; EN, European Standard. Mole.

## I. INTRODUCTION

A search for alternative source of raw material for the production of fuel has increased in recent years. This is as a result of the fact that man has discovered that the fossil fuels that he long depended on as a source of raw material for petrol and diesel engines are being fast depleted without replacement or regeneration as a result of non-renewability of the fossil, particularly crude oil. Many of these researches or searches have been based on plant product. Similarly, search for alternative source of raw material for the production of fuel has increased in recent years. This is as a result of the fact that man has discovered that the fossil fuels that he long depended on as a source of raw material for petrol and diesel engines are being fast depleted without replacement or regeneration as a result of non renewability of the fossil particularly crude oil.

Nowadays, fossil fuels mainly petroleum, natural gas a-

nd coal have been playing an important role as major energy resources worldwide. However, these energy resources are non-renewable and are projected to be exhausted in the near future. The situation has worsened with the escalating energy consumption worldwide due to rapid population growth and economic development. Global emission of CO<sub>2</sub> and other harmful gases such as CO, SO<sub>2</sub>, and NO<sub>x</sub> and particulate generated by fossil fuel combustion have led to serious green house effects on the environment. These include global warming, depletion of the ozone layer, increase in mean sea level, acid rain, and the deterioration of human health and the environment (Guan et al.2009). It has generated a lot of concern and has led to an urgent need for the identification of new energy resources that are environmentally friendly (Shen et al, 2010). Biodiesel is an alternative diesel fuel made from biological sources, primarily vegetable oils, but to a lesser extent, frying oils and animal fats. It is produced by the homogeneous catalytic transesterification or alcoholysis reaction (usually methanolysis). The catalyst being either a base or an acid (Al-zuhair 2007; Papadopoulos et al, 2010). Biodiesel can be used as a basis for a clean substitute for fossil fuel without any modification of diesel engines, boilers or other combustion equipment (Saydut et al 2008).

Many researchers have reported biodiesel production in many ways depending on the feedstock (Karmee and chadha 2005; Kaul et al. 2007; Chakraborty et al.2009; Papadopoulos et al. 2010). However, the critical issues in the production of biodiesel are the availability and cost of the feedstock, cultivation requirement, oil yield and oil composition, the short comings of using edible over non edibles oils for biodiesel production and the techniques available for converting non edible oils to biodiesel (Gui et al 2008). This paper looks into the processing and production of biodiesel from the seed oil of *Cucumis melo* (sweet melon) and the evaluation of the oil parameters of the biodiesel produced.

## II. MATERIALS AND METHOD

### *Collection and Preparation of Seed Samples*

Sweet melon fruits were obtained from Bara village along Bauchi-Gombe road in Alkaleri local government of Bauchi state of Nigeria. The seed were removed from the fruits washed and were subjected to sun drying over a period of time. The dried seed were milled into powder using mortal and pestle. The milled powder was stored in an air-tight container.

### *Reagents*

All the reagents used in this work were of Analar grade

and purchased from British Drug House (BDH), Poole England.

#### Oil Extraction

Oil from the powdered seed of sweet melon *Cucumis melo* was extracted by the method described AOAC (1980) at the end of the extraction the solvent was evaporated in a rotary evaporator. Free fatty acid were determined as described in Schliecher *et al.* (2009). The extracted oil which is made up predominantly of 71.90% unsaturated fatty acid and 28.10% saturated fatty acid was then transesterified.

#### Biodiesel Production

The transesterification process proceeded with 5:1 molar ratio of methanol/oil and 0:50 g hydroxide pellets. The methanol was slowly added into weighed 0:60 g KOH in a 150ml conical flask while stirring until the whole KOH pellets was dissolved to form methoxide solutions. The oil was heated at 50°C and the methoxide was slowly added over a period of 30 min with continuous and slow stirring using a magnetic spin stirrer. The reaction mixture was then allowed to stand over night. A crude methyl ester phase at the top was formed and a glycerol phase at the bottom of the mixture on settling using a separating funnel. The lower layer is run-off which contains most of the glycerol realized during the reaction. The catalyst is removed by warm water washing and the excess methanol and water in the ester phase is removed by evaporation under atmospheric condition (Eevera *et al* 2009).

#### Test for Fuel Quality Parameters

##### i. Density Determination:

The weight of an empty 100-ml beaker was determined. A specific volume of biodiesel was added to the 100-ml beaker and the weight of the oil and beaker determined. The density is calculated using the formula.

$$\text{Density (p)} = \frac{w_2 - w_1}{v}$$

Where  $w_1$  = weight of empty beaker;  $w_2$  = weight of beaker and biodiesel;  $v$  = volume of biodiesel. The density obtained was compared to the density of diesel D<sub>2</sub> (Reece and Peterson 1993.)

##### ii. Viscosity Determination:

The method of liquid flow through an aperture in a cup was used for the determination of viscosity of biodiesel. A Prolabo viscometer was used for the determination of viscosity. Prolabo cup number 4 viscometer was washed and rinsed and allow to dry. The measurement of viscosity of the biodiesel was carried out by taking the number of seconds it takes for a fixed quantity of biodiesel (60 cm<sup>3</sup>) to flow through a small orifice of standard length and diameter at a specified temperature. This was done by filling the cup with 60cm<sup>3</sup> of the biodiesel after closing the aperture with a finger beneath. The finger was then removed from the orifice and the stopwatch started. The stopwatch was stopped after the last drop of the biodiesel and the time taken for the biodiesel to flow out was recorded.

The viscosity was calculated by multiplying the time in seconds by the standard length and diameter of the small orifice at a specified temperature (John and Tyler 1976).

##### iii. Cloud Point Determination:

An improvised method was used for the cloud point de-

termination 5ml of biodiesel was poured into a test tube and the clamp carrying the test thermometer held tightly. The position of the thermometer was adjusted to allow the thermometer rest at the bottom of the tube for uniformity. The test tube was placed in an ice bath and the set up inspected at intervals for cloud formation. The temperature at which a distinct cloudiness formed at the bottom of the test tube was recorded (Reece and Peterson 1993).

##### iv. Flash point Determination:

The flash point was determined according to ASTM D93 method for flash point by pensky-Martens Closed Cup Tester (Anwar *et al* 2010). The temperature was then compared to the flash point of diesel D<sub>2</sub>.

##### v. Pour Point Determination:

A modified method using a -4°C cooling bath was used for the pour point determination. 5ml of the biodiesel was poured into a test tube and clamp with a wooden clamp bearing a thermometer. The sample was allowed to freeze in an ice bath. It was then removed and tilted on the clamp with the thermometers. The setup was observed at intervals and the lowest temperature at which the biodiesel was observed to flow was recorded as the pour point (purnanand *et al* 2009).

##### vi. Acid Value Determination:

Acid value determination was carried out according to the method described by Onwuka (2005).

##### vii. Cetane Number (CN) Determination:

CN was determined using the estimated Saponification Value (SV) and iodine value (IV) via calculation from the equation below (Meher *et al* 2006; Eevera *et al*, 2009).  $CN = 46.3 - 54.58/SV - 0.225IV$ .

##### viii. Higher Heating Value (HHV) Determination:

The higher heating values were determined using the estimated Saponification value (SV) and iodine value (IV) via calculation from the equation below (Eevera *et al* 2009).  $HHV = 49.43 - 0.041(SV) + 0.0051(IV)$ .

##### ix. Carbon Residue (CR) Determination:

CR determination was carried out by the method described by Demmering *et al* (1995).

#### Sampling and Statistical Analyses

The results are present as mean  $\pm$  SD of triplicate readings. Comparison of mean biodiesel quality parameters between the methyl esters produced using either NaOH or KOH were done using the Mann – Whitney U test and  $p < 0.005$  were considered significant.

### III. RESULTS AND DISCUSSION

The results show that the physical and chemical properties of CMSO all were within the recommended limits as specified in the literature.

The conversion of CMSO to methyl esters was achieved by using molar ratio 5:1 methanol to oil with catalyst concentration of 0.5g KOH and 0.65g NaOH at 50°C for 30 min. Maximum conversion yields of 64% and 46% were obtained for KOH and NaOH catalyzed processes respectively. The Transesterification is commonly carried out with an excess amount of alcohol in order to shift the equilibrium to the product (methyl ester). But a higher amount of alcohol requires longer time for the separation

of the ester layer from the water layer. This is due to the fact that methanol with one polar hydroxyl group can only work as simulifer which enhances emulsion (Zhang *et al* 2003) the higher yield of KOH catalyzed process compared to the NaOH catalyzed process might be due to the fact that potassium is more reactive than sodium. This agrees with the findings of others (Dorado *et al* 2004; Meher *et al* 2006 Rashid and Anwar 2008). Who also found that KOH catalyst was the most effective in the methanolysis of *pongia pinnata* and *Brassica carinata* a finding they ascribed to the varied chemical nature of the feedstock oils used in the biodiesel production. The fuel quality of the methyl esters produced were evaluated in accordance to American Society for Testing and Materials (ASTM) European (EN) and German (DIN) standards. The quality of the methyl esters are of importance for better engine performance characteristics. The results are presented in table 1.

#### Density

Density is a key fuel property which directly affects the engine performance characteristics such as CN and higher heating values which are both related to density (Ertan *et al* 2008). The density of CMSO methyl ester was 0.87 to 0.86 g/cm for methyl ester using KOH and NaOH respectively. Both values fell within the acceptable limits of 0.86-0.90g/cm<sup>3</sup> recommended by EN 14214 and 0.87-0.90g/cm<sup>3</sup> recommended by ASTM D6751-02 (Peng *et al* 2008). While the density of diesel fuel ranges between 0.075- 0.840 g/cm<sup>3</sup> (Demirbas 2009). The density of diesel fuel is generally lower than those of biodiesel. This negative property needs more diesel fuel injected into the combustion chamber in order to gain the same power from the engine. The density of biodiesel also varies depending on the fatty acid composition and their purity (Ertan *et al* 2008).

A change in the fuel density will influence engine output power due to a different mass of fuel been injected, since diesel fuel injection system measures the fuel by volume. A change in fuel density will also affect the start of injection pressure and spray characteristics, so that they affect engine performance, combustion and exhaust emission (Bahadur *et al* 1995).

Table 1. CMSO Methyl Ester Fuel Quality Parameter Analysis

FUEL PARAMETERS	CMSO Methyl ester using KOH catalyst	CMSO Methyl ester using NaOH catalyst
Density(g/cm <sup>3</sup> )	0.98	0.98
Viscosity(mm <sup>2</sup> /sec)	13.22	13.22
Cloud point	3	3
Flash point(°C)	210	210
Pour Point(°C)	4	4
Acid Value(mgKOH/g)	0.96	0.96
Cetane Value	35.45	35.45
Higher Heating Value (MJ/Kg)	40.19	40.19
Carbon Residue	0.03	0.06

#### Viscosity

Viscosity is an important property of any fuel, as it is an indication of the ability of a material to flow. It was identified that viscosity is one of the most significant properties that affect biodiesel as fuel. It reduces with

increase in unsaturation. Viscosities of saturated ethyl or methyl esters are slightly higher than those of unsaturated ethyl or methyl esters. The higher the viscosity the lower the ester content (Candeia *et al* 2008). The viscosity of CMSO methyl ester is 13.22mm<sup>2</sup>/sec. It is higher than the recommended value for petro diesel given by ASTM D445 limits as ranging between 1.9- 6.0mm<sup>2</sup>/sec.

Biodiesel is denser and slightly more viscous than diesel and also presenting a narrower boiling points interval which indicates that the fatty acids have similar boiling points as compared to the wide variety of hydrocarbon composing the petro diesel. The ASTM D975 limit for viscosity of diesel is 2.60mm<sup>2</sup>. The viscosity of diesel fuel like density is also generally lower than that of biodiesel.

#### Cloud Point

The cloud point is the temperature at which wax first become visible when the fuel is cooled. It is an important parameter for low temperature application of a fuel (Prakash 1998). The cloud point of both CMSO methyl ester using either KOH or NaOH catalyst are the same 0°C.

Berrios and skelton (2008) recommended the cloud point of biodiesel ranging 0 to -5°C and Georgogianni *et al* (2007) recommended a limit of -3° C. White Sinem *et al* (2009) gave diesel fuel cloud point as -6°C and Anh *et al* (2008) gave cloud point for conventional diesel as 0°C. The cloud point (3°C) for CMSO methyl esters indicates that this biodiesel can be used for cool climate, without flow problems at low temperature.

#### Flash Point

The flash point of biodiesel is the temperature at which the fuel becomes a mixture that will ignite when exposed to a spark of flame. Flash point is one of the main properties that are associated with biodiesel composition (Candeia *et al* 2008; Anwar *et al*, 2010). Flash point is related to the amount of methanol and is also related to the amount of un converted triglycerides or a low content of mono alkyl esters. The flash point of both CMSO methyl ester using either KOH or NaOH catalyst are 210 and 210°C respectively. The values are higher than the ASTM D93 established maximum value of 130°C and minimum value of 130°C (Candeia *et al*2008) DIN EN 14214 establish flash point of biodiesel to be > 120°C (Peng *et al* 2008) ASTM D975 established diesel flash point as ranging between 52-96°C.

Biodiesel generally, has a higher flash point than diesel hence the high values of both CMSO methyl esters using either KOH or NaOH catalyst is an indication that it is less likely to ignite accidentally and also ensures more safety in handling and storage and thus a safer fuel than fossil diesel.

#### Pour Point

The pour point is the temperature at which the amount of wax from the solution is sufficient to gel the fuel, thus it is the lowest temperature at which the fuel can flow (Prakash 1998; Purnanand *et al* 2009). The pour point for both CMSO methyl ester using KOH or NaOH catalyst are the same 4°C. The ASTM D6751 -02 biodiesel standard established the biodiesel pour point to range from -15 to 10°C likewise DIN 14214 standard, while ASTM D975

established the diesel pour point standard as  $-35$  to  $-15^{\circ}\text{C}$  (Peng *et al* 2008 ) Anh and Tan (2008) reported that the pour point of conventional diesel as  $-12^{\circ}\text{C}$ . The CMSO methyl esters have their point within the range established by both ASTM and EN standards. Higher pour points in fuels affect its use in cold environments, because they have to be kept warm by heating the electric heater insulated tanks (Reece and Peterson, 1993).

#### Acid Value

The acid value indicates the level of free fatty acid in biodiesel. The acid value of CMSO methyl ester using KOH catalyst is  $0.98\text{mg KOH/g}$  while CMSO methyl ester using NaOH using catalyst is  $0.96\text{mg KOH/mg}$  which fall near the acceptable limit recommended by ASTM D6751 as  $0.80$  max and EN-14214 limit of  $0.5$ max. The acid value of biodiesels generally is lower compared to the acid value of  $0.104\text{ mgKOH/g}$  (Maumita *et al* 2009). The acid value for both KOH and NaOH catalyzed biodiesels are high showing that the free fatty acid content is high and the biodiesels cannot cause much operational problems such as corrosion and pump plugging caused by corrosion and deposit formation (Candeia *et al* 2009).

#### Cetane Number (CN)

The CN is a measurement of ignition performance of a fuel. It is one of the important parameter which is considered during the selection of methyl esters for use as biodiesels. It is influence by structural features of fatty acid alkyl esters such as chain length degree of unsaturation and branching of the chain. Better ignition quality of fuel is always associated with higher CN value (Saydut *et al* 2008; Anwar *et al* 2010). CN affects a number of engine performance parameters like combustion, stability drivability white smoke noise and emission of CO and hydrocarbons (Rhamadas *et al* 2006).

The CN of both methyl ester was at the same value of  $35.45$  which is a little below the ASTM D6751 limit of  $47$  Germany (DIN V51606) standard of  $49$  and European organization standard of  $51$ (Eevera *et al* 2009). The CN of biodiesels are generally lower than that of diesel D<sup>2</sup> which is given as  $46$ . The reason for the low CN is due to the fact that biodiesels fuels from high saturated feedstock ( $90\%$  and above) would exhibit alkyl chain with higher fatty acids than those from less saturated feed stock, which is the case with CMSO methyl ester (Maumita *et al* 2009).

#### Higher Heating Value (HHV)

The higher heating value of a substance is defined as the amount of heat released during the combustion of a specified amount of that substance. The higher heating value of biodiesel is relatively lower compared to those of petro diesel, D2 and that of gasoline or petroleum oil but higher than coal. (Demirbas 2009). The HHV for CMSO methyl esters was  $40.19\text{ MJ/kg}$ , which is within the range recommended for biodiesel ranging between  $39-41\text{ MJ/kg}$  and  $43\text{ MJ/kg}$  for petrol diesel (Demirbas 2009). Low heating value of fuel mainly causes de-rating of engine power. But the use of petrol diesel blend with such methyl esters would lower the viscosity to desired level (Maumita *et al.*, 2009).

#### Carbon Residues (CR)

CR is an important measure of the tendency to form carbonaceous deposit in engine. The part remaining after the sample has been subjected to thermal decomposition is the CR. It is particularly important in engine because of the possibility of clogging the fuel injectors, corrosion and cracking of component. The most common cause of excess CR in B100 is an excessive level of glycerine (Bradin 1996). The CR of CMSO methyl ester were  $0.03\text{wt}\%$  for KOH catalyzed methyl ester and  $0.06\text{wt}\%$  for NaOH catalyzed methyl ester. The ASTM D6751 recommended limit of CR in biodiesel is given as  $0.050$  max (Ertan and Mustafa 2008). Bayense *et al.*, (1996) also give acceptance limit of  $0.05$  max%. The CR for diesel fuel is usually higher than biodiesel. The ASTM D4530 gave diesel standard limit of CR ranging between  $0.1-0.2\text{ wt}\%$  while the EN14214 gave diesel CR limit as  $0.3\text{max}\%$  (Maumita *et al.*, 2009). The research result shows that the tendency of CMSO methyl ester to form carbonaceous deposits in engines using potassium catalyst is limited while sodium hydroxide catalyzed biodiesel is likely to form slight CR which could be due to incomplete conversion of the oil to biodiesel due to the strength of NaOH catalyst compared to KOH catalyst.

## IV. CONCLUSION

This research study has shown that CMSO methyl ester has most of the fuel quality parameters meeting the international biodiesel standards. The result also show that KOH catalyst gave a higher yield of biodiesel compared to that of NaOH catalyst with KOH yielding  $64\%$  and NaOH yielding  $46\%$ . Thus, biodiesel from sweet melon *Cucumis melo* seed oil can be used as a feasible alternative as diesel replacement fuels.

## REFERENCES

- [1] Al-Zuhair, S. (2007). Production of biodiesel possibilities and challenges bio fuel. *Rioproducts and Riorefining* 1, 57-66.
- [2] Anh, N.P. & Tan, M.P. (2008). Biodiesel production from waste cooking oils. *Fuel journal* 87,3490-3496
- [3] Rashidah, U.A. & Anwar, A. (2008). Okra (*Hibiscusesculentus*) seed oil for biodiesel production applied Energy 87, 779-785.
- [4] Association of Official Analytical Chemists (AOAC) (1980). Official methods of analysis (19<sup>th</sup> edn.) William Horwitz Washington DC USA Pp. 56-135.
- [5] Bahadur, N.P. (1995). Liquid hydrocarbon form catalytic pyrolysis of sewage sludge. *Lipid and canola oil. Evaluation of fuel properties. Energy Fuel* 9,248-256.
- [6] Berrios, M. & Skelton, R.L. (2008). Comparison for purification method for biodiesel. *The chemical Engineering journal* 144,459-465.
- [7] Bradin, D.S. (1996). Biodiesel Fuel. US Patent 5578090. Available online <http://www.freepatentsonline.com>
- [8] Candeia R.A, Silva M.C.D & Carvalho F.J.R. Barasilino MGA. Bocado T.C. Santos I.M.G & Souza A.G (2009). Influence of soybean biodiesel content on basic properties of biodiesel diesel blend fuel 88, 738-743
- [9] Charkraborty M Buruah DC, Konwer D (2009). Investigation of terminalia (*Terminalia bellerica* Robx) seed oil as prospective biodiesel source from North-East India. *Fuel Processing Technology* 90, 1435-1441.
- [10] Demirbas A (2009). Progress and recent trends in biodiesel fuel. *Energy Conversion and Management Journal* 50, 14-34.

- [11] Dorado MP, Ballesteros E., Lopez FJ Mittelbach M (2004) optimization of alkali catalyzed Transesterification of Brassica carinata oil for biodiesel production Energy Fuel 18, 77-83.
- [12] Eevera T. Rajendra K. Saradha S. (2009). Biodiesel process optimization and characterization to assess the suitability of the production for varied environmental Condition. Renewable Energy 34,762-765.
- [13] Ertan A, Mustafa C (2008). Determination of the density and viscosity of the biodiesel blend Renewable Energy Journal 33, 3633-3630.
- [14] Geogogianni K, Kontominas MG Tegon E, Avlonitis D & Vergis V (2007) Biodiesel production and process parameters of alkali catalyzed Transesterification of waste frying oil. Energy Fuel 21, 3023-3027.
- [15] Gui M.M, Lee K.T & Bhatia S (2008) Feasibility of edible oil Vs non edible oil Vs waste edible oil at room temperature at various co-solvents. The chemical engineering Journal 146,160-161.
- [16] Karmee S.K, Chadha A (2005) preparation of biodiesel from crude oil of pongomia pinnata Bio resource Technology 96, 1425-1429
- [17] Kaul S. Sasena RC, Kumar A, Negi MS, Bhatnagar AK, Goyal HB & Gupta AK (2007) corrosion behavior of biodiesel from seed oil and Indian origin on diesel engine parts Fuel Processing Technology 88,303-307
- [18] Maumita C, Baruah DC & Konwer D (2009) Investigation of terminalia (Terminalia belerica Roxb) seed oil as prospective biodiesel source of North-East India Fuel Processing technology 90, 1435-1441.
- [19] Meher L.C, Vidya S.S & Sharmagadda S.N.N. (2006). Optimization of alkali catalyzed Transesterification of pangamia pinnata oil production of biodiesel
- [20] Onwuka G.I (2005). Food Analysis and Instrumentation. Theory and practice Naphthali prints Lagos 219.
- [21] Papadopoulos C.E, Lazaridon, A. Kountsoumba A., Kokkinos A.C, Nikoulau N (2010). Optimization of cotton seed biodiesel quality (critical property) through modification of its FAME Composition by highly selective homogeneous hydrogen ration Bioresource Technology 101, 1828-1819
- [22] Peng B-X, Shu J-F, Wang G-R, wang D-Z, Han M-H (2008). Biodiesel production from waste oil feedstock by solid acid catalyst process safety and Environmental Journal 86,441-447
- [23] Prackash CB (1998). A Critical Review of Biodiesel as transportation fuel in canada. A technical report GCSI. Global Change Strategies International Canada Available Online online <http://www.diesel.duck.ca.library> on 23/11/17.
- [24] Ramadhas AS, Jayaraj S, Muraliedharan C, pndmarkumari K (2006) artificial neural network used for the production of catane number of the diesel. Renewable Energy 31, 2524-2533.
- [25] Rashid U, Anwar F (2006). Production of Biodiesel through optimized alkaline Transesterification of rape seed oil. Fuel 87, 265-273.
- [26] Reece DI., Peterson CL. (1993) A report on the Idaho. On road vehicle test with RME and neat rape seed oil as an alternative to diesel fuel ASAP Paper No. 93-5081. International summer meeting Spokane Washington DC 335 Pp. Technology 99, 6656-6666.
- [27] Scleicher T, Werkmeister R. Russ W. Meyer-pitroff R (2009) microbiological stability of biodiesel-diesel mixture. Biosource Technology 100, 724-730
- [28] Shen J., Zhu S, Liu X., Zhang H & Tan J (2010). The production of chemental and management 51. 983-987
- [29] Sinem C. Metin G. Ahmet B. Ali K, Yakup C (2009). Biodiesel production from pomace oil and improvement of its properties with synthetic manganese additive. Fuel Journl 88. 534-538
- [30] Zhang V., Dube M.S.A, Mclean D & Kates M (2003). Biodiesel production from waste cooking oil. 2 Economic assessment and sensitive analysis. Biosource Technology 90. 229-240.

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