INTERNATIONAL JOURNAL OF PHYTOFUELS AND ALLIED SCIENCES
(A Journal of the Society for the Conservation of Phytofuels and Sciences)
(http://www.phytofuelsciences.com) (ISSN 2354 1784)

Production, Characterization and Performance Evaluation of Biodiesel from Avocado Seed Oil Using Autodesk Inventor Fusion 2013

*Isah[1],M., Oluwole[1], F.A., Sulaiman[2], A.T. and Abdulrahim[1], A.T.
[1]Department of Mechanical Engineering,
University of Maiduguri, P.M.B. 1069, Maiduguri, Nigeria.
[2]Department of Mechanical Engineering,
Bayero University Kano, P.M.B. 3011, Kano, Nigeria.
Corresponding Author e-mail address:_senismag@gmail.com)_

ABSTRACT

The study examined the production, characterization and performance characterization of biodiesel prepared from avocado seeds. The Avacado SeedOil (ASO) was extracted from the seed through both mechanical and solvent extraction methods. 354 ml oil was extracted from1.2 kg seeds ofwindslowson cultivar, having 30% oil content. The extracted oil was characterized and converted to biodiesel using transesterification method with operational condition of methanol to oil molar ratio of 6:1, reaction time of 6 mins, and reaction temperature of 60 ^{o}C. TheAvacado biodiesel (ABD) produced was characterized to determine the fuel properties and evaluated on the basis of emission quality. The results of the oil properties indicate thatthe specific gravity,density, acid value, free fatty acid (%FFA), viscosityand higher heating valuewere0.9155, $915.5 kgm^{-3}$,5.25 mg KOH/g, 0.104%,35.9 mm^2/s and 56.05MJ/kg respectively. The results of biodiesel characterized showed that thespecific gravity,density,viscosity,flash point,acid valueand heating valuewere0.869, 869 kgm^{-3}, 3.59461 mm^2/s, 80°C, 0.76 mgKOH/g and41.113MJ/kg respectively. It was noted that the emission quality wasCO, 0.75%; PM, 0.07%;, NOx 5.04S 2.33%.for Carbon II Oxide, Particulate Matter, Oxide of Nitrogenand Sulphur contentrespectively.The ABD properties were compared with several limits prescribed in the ASTM D675-02 of biodiesel standards. It was concluded

that the properties of the extracted Avacado oil and the biodiesel produced from the oil met ASTM D675 standard. The emission gave good quality.

Keywords: Avocado seed oil, Windslowson cultivar, Solvent extraction, Transesterification, Flash point, Autodesk investor.

INTRODUCTION

It is an undisputable fact that there is a universal demand for vegetable oil due to its use in domestic cooking as an ingredient for other food production such as baking and frying of snack foods and as a raw material for the manufacture of soap, body/hair oils and detergents (Peter and Ann, 1992).

The avocado (*Perceaamericana*) belongs to the Lauraceae family of tropical and Mediterranean trees and shrubs; other members of this family include: Lauren cinnamon, Saffras and green-heart (a timber of the Gulanas). Originally, avocado pears are generally grown in the tropical part of the world, including countries like South America, Central America, West Indies, Caribbean and Mexico. Nowadays, they are grown in Cameroon, Nigeria, Ghana etc. In Nigeria, the various places where Avocado is planted include: South East (Obudu area in Calabar), North Central (Pankshin, BarakinLadi, Vom in Jos, Plateau State), Mambila Plateau in Taraba State and Shebeshi and Atlantika, Southeast of Yola, the capital of Adamawa. The species of Avocado cultivated in Nigeria are: Windslowson and Hass, having oil contents of 30% and 22% respectively (Maitera*et al.*, 2014).

Avocado seed is a biomass material that contains triglycerides and has low FFA (free fatty acid) content of 0.367%. It can be processed to biodiesel through transesterification. Researchers tried to examine the potential of avocado seed as alternative energy resources that is environmental friendly and can meet the domestic energy demand (Ikhuoria*et al.*, 2001).

Maitera*et al.* (2014) carried out a proximate and elemental analysis of avocado fruit. In their investigation, it was found that the moisture content was 64.73% while oil content was 36.5%. The fruits were wet digested for some mineral elements; these elements and their respective composition are as follows: Na, 0.23 mg/kg, K, 2.04

mg/kg, Fe, 0.069 mg/kg, Ca, 0.064 mg/kg and Mg, 0.103 mg/kg. Other parameters studied include crude fibre 4.03%, crude protein 1.65% and ash content 12.36%. The extracted oil was characterized and the results are: saponification value (as in oleic acid) 0.186 mgKOH/g, free fatty acid 0.180 mgKOH/g, Iodine value 0.82gI_2/100g, and specific gravity obtained at 25°C was 0.915.

Rachimeolla*et al.* (2009) carried out an investigation on the production of biodiesel using a Hass avocado seed cultivar. It was confirmed that the optimum condition for biodiesel yield was obtained at a molar ratio of 1: 6 (oil to alcohol). They also concluded that dry washing method gave the best yield of the biodiesel, as compared to that of the water wash. The results of their findings showed that the dry washing gave the yield of 84.5678% while the water wash gave 82.7119% of the biodiesel yield.

Arifin, (2009) carried out investigations on the Production of Biodiesel from Waste Cooking Oil (WCO) and RBD Palm Oil Using Batch Transesterification Process. She equally carried out the study on the performance of yield and purity of biodiesel from WCO as the starting material with different catalyst ($NaOCH_3$) concentration and reaction time via single step batch transesterification process. In her results, the higher conversion was obtained when RBD palm oil which is 98.2% yield and 97.5% purity instead of 96.8% yield and 94.7% purity in WCO used as the raw material.

Nada, (2011), carried out a study on the manufacturing of biodiesel from the used vegetable oil. He defined the requirements for biodiesel production by the esterification process, testing its quality by determining some parameters such as density, kinematics viscosity, high heating value, cetane number, flash point, cloud point and pour point and comparing it to Diesel fuel, testing the engine performance, testing the emissions of biodiesel and comparing it to diesel emission, and the strategic issues to be considered to assess its feasibility, or likelihood of succeeding.

Sivaramakrishnan*et al.* (2006), experimented on the performance optimization of Karanja biodiesel oil. Their work was aimed at optimizing the direct injection (DI) single cylinder diesel engine with respect to brake power, fuel economy and emissions through experimental investigations and Design of Experiment(DOE) methods. A single cylinder 5.2 kW diesel engine was selected for test.

Waziri*et al.* (2012) carried out an experiment on the development of mathematical model for the transesterification of *Jatrophacurcas* seed oil in heterogeneous catalyst. He developed a model equation for the prediction of biodiesel yield in terms of both coded and actual factors using Design-Expert 6.0 software. He validated the model by substituting the experimental data, at various conditions of catalyst concentration, methanol/oil, reaction time and stirrer speed. In comparison, the result of their experimental values and predicted values were in close agreement. In their work, the signal noise ratio (SNR) was used to optimized the performance of the engine in terms of break thermal efficiency (BTHE), break specific fuel consumption (BSFC) and emission of the diesel engine, using controlled factors: compression ratio (CR), nozzle pressure (NP) and injection timing (IT). They used empirically developed mathematical model, which is a link between dependent variables and control parameters and compared with their experimental results.

This study aimedattheproduction, characterization and performance evaluationof oil and biodiesel from avocado seed oil (specific gravity, density,acid value, viscosity, flash point and higher heating value) and to model a virtual biodiesel engine using Autodesk fusion, simulate the model using blender and python as plug-in to obtain the emission quality.

MATERIALS AND METHODS

The methods adopted in this study are staged into three: Preliminary stage, main reaction stage and purification stage. In the preliminary stage,the oil was extracted, distilled and degummed. The extraction was carried out using both mechanical extraction and solvent methods.

TheAvacadooil extracted were distilled in an electric temperature regulator oven, to expel the remnants of the moisture content present.

After the distillations, the oil became gummed (thickened). Hydrogen tetraoxo phosphate V (H_2PO_4) was used in degumming the oil.

Characterization of the Avocado Seed Oil (ASO):

a) *Determination of Specific Gravity (SG) of the Oil:*

Hydrometer was used to measure the SG of the oil at 25^{0}C (Oluwole*et al.*, 2014)

b) *Determination of the Density of the Oil:* Density is the weight per unit volume. Oils that are denser contain more energy. The density was determined by using the SG obtained above with the density of water

c) *Determination of the Acid Value of the Oil:* Acid value (or "*neutralization number*" or "*acid number*" or "*acidity*") (Zhu *et al.*, 1997). The acid value was determined using equation 1:

$$\mathrm{AV} = \frac{N \times V \times M}{\mathrm{W}} - - - - - - - - - - - - - - (1)$$

Where $N =$ The normality of aqueous solution of KOH (0.1N), $V =$ Volume of titrant used for titration (25ml), $M =$ Molecular weight of KOH (4.2mol), $W =$ Weight of oil sample (2g).

Determination of the Percentage Free Fatty Acid (%FFA): Percentage free fatty acid ($\%FFA$) content of the oil was calculated empirically using the acid value previously determined as follows:

$$\%FFA = \frac{AV}{0.503} - (2)$$

Where: $\%FFA =$ Percentage free fatty acid contents in terms of oleic acid (Anonym, 2015)

d) *Determination of the Viscosity of the Oil:*
The viscosity was measured by a viscometer (Plate 6). The viscosity was read off as $35.9mm^2/s$(Oluwole*et al.*, 2014).

e) Higher Heating Value (Calorific Value): According to Sivaramakrishnan and Ravikumar (2006), the relationship between the higher heating value (HHV) and viscosity of a vegetable oil is given by:

$$HHV = 0.4625v + 39.450 - - - - - - - - - - - (3)$$

The main reaction consists of the experimental design, experimental set-up and production procedure.

In the experimental design, the production of biodiesel for the percentage of biodiesel yield was designed for two selected factors: Methanol to ASO molar ratio and the temperature, with respect to the washing method. The selection of parameters was based on research works and practical considerations in the literature. The operational conditions for this stage are:

retention time of 60 minutes and 1% wt. NaOH toward oil and are based on the literature data (Rachimoellah*et al.*, 2009). The operational variables are molar ratio of oil to methanol (1:6) and temperature reaction (40°C, 50°C, and 60°C). The upper temperature level (60°C) was selected, since theoretically, the boiling point of methanol is 64.7°C. The molar ratio (1:6) was the theoretically declared maximum yield giving molar ratio (Rachimoellah*et al.*, 2009). The reaction time and mixing intensity were fixed at 1 $hour$and 350 rpm respectively for all experimental runs.

Methanol and Sodium hydroxide mixture was prepared as Sodium methoxide. This mixture was agitated continuously until all the Sodium hydroxide dissolved completely. The reactor was then charged with50 mlof refined oil and the methoxide solution. Then the reactor assembly was heated to the desired temperature by using the circulating thermostat. Mixing, assisted with magnetic heat stirrer, was started immediately by gradually increasing the intensity to 350 rpm. After **1hour** of the reaction time, the mixture was then transferred to a clean separating funnel and allowed to separate. After the separation was completed, the biodiesel layer was collected and transferred to another separation funnel for washing, as the purification stage.

Evaluation of AvacadoOil Biodiesel

Characterization of the Avocado Biodiesel (ABD)

a) ***Specific gravity (SG) at 15°C***: The procedures described in ASO characterization was used to determine the specific gravity of the ABD.
b) ***Determination of Density of the Biodiesel:***The procedures described in ASO characterization was also used to determine the density of the ABD.
c) ***Determination of Acid Value of the Oil:***The acid value was determined using the procedures described in ASO characterization.
d) ***Viscosity (mm^2/s):***The viscosity was measured using “V8 Viscometer”.
e) ***Flash point (°C):***The flash point of the biodiesel was determined using a Pensky Martens Flash Point Tester.
f) ***Higher Heating Value (Calorific Value):***This was determined using the procedures described in ASO characterization.

An Autodesk Investor Fussion 2013 was used for the design of the engine parts used for the evaluation (Table 1).

Table 1: Specification of Biodiesel Engine

Make	***Specification***
Model	DAF 10
Engine power	5.2 KW
Rated Brake Power (bhp/kW)	9.6/7
Rated Speed (rpm)	1500
Number of cylinder	One
Bore X Stroke (mm)	102 x 110
Compression Ratio	17.5:1
SFC at rated hp/1500rpm	251g/kwh (185g/bhp-hr)
Inlet valve Open (Degree)	4.5 BTDC
Inlet Valve Closed (Degree)	35.5 ABDC
Exhaust Valve Open (Degree)	35.5 BBDC
Exhaust Valve Closed (Degree)	4.5 ATDC
Fuel Injection Timing	26BTDC

Source: (Pooja and Mayur, 2012)

After the design, specification was imputed, a virtual biodiesel engine (Figure 1) was modeled. The model was based on the specification of the biodiesel engine (Table 1).

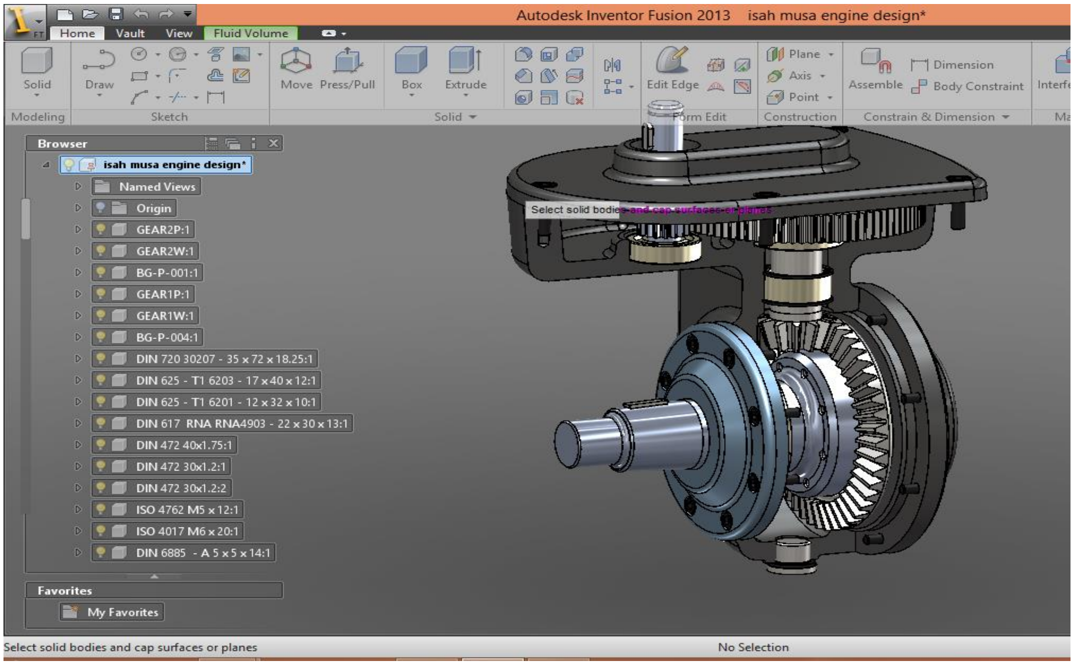

Figure 1: A Virtual Biodiesel Engine model

RESULTS AND DISCUSSION

Table 2 presents the results of the Avacado oil properties. It was observed from Table 1 that the Specific gravity and density of the Avocado seed oil were 0.9155 and 915.5kgm^{-3} respectively, and werewithin the range of the ASTM (675-02), which were0.915 and 915kgm^{-3} respectively. The viscosity of the purified ASO was slightly higher than the standard value at 34℃ which was 35.7 mm^2/s, however, the observed difference was not significant.

The acid value of the purified ASO of $\mathbf{5.25}$ was within the range of the ASTM 675-02 value reported in the literature which was$\mathbf{5.200}$. The percentage of Free Fatty Acid (%FFA) (Table 1) of the purified ASO$\left(\mathbf{0.104\ mg\frac{KOH}{g}}\right)$ is suitable for base catalyzed transesterification reaction (acid value of the oil should be below $\mathbf{2\ mgKOH/g}$) and preferably $<$ $\mathbf{0.05}$%, according to ASTM and EU standard (Martinez-Herrera *et al.*, 2006). Therefore, the oil did not need any further treatment and hence suitable for the production of biodiesel.

Table 2: Physico - Chemical Properties of Avocado seed Oil (ASO)

Properties	*Purified ASO*	***ASO***Ikhuoria*et al.*, 2001 (ASTM 675-02)
Specific gravity	0.9155	$0.915 - 0.916$
Density @ 15°C (kgm^{-3})	915.5	$-$
Acid value ($mgKOH/g$)	5.25	5.200
%FFA (%)	0.104	$0.367 - 0.82$
Viscosity @ 34°C (mm^2/s)	35.9	35.7
Higher Heating Value (MJ/kg)	56.05	$-$

Table 3 presents the results of Avacado biodiesel (ABD) properties. It was noted that the specific gravity and density of the avocado biodiesel are within the range of standard values of biodiesel, $0.850 - 0.890$ and$850 - 890$ for SG and density respectively.

The viscosity of the biodiesel,$3.59461 mm^2/s$ was within the range of the ASTM D 675-02, though it was higher than the lower limit of the standard biodiesel$2.3mm^2/s$,probably due to the fact that biodiesel produced in the laboratory was not completely converted to biodiesel. This means that it still contains little amount of ASO and other impurities since centrifugation was not used.

The resulted flash point for the biodiesel was within the specified standard limits of ASTM i.e. (< 100). As the result shows the flash points of the test 80°C below the maximum limit, is the indication of the volatility of the biodiesel.

The acid value of the avocado biodiesel (Table 3) was lower than that of the ASTM (675-02) biodiesel and this was probably due to the transesterification and purification processes.

The heating (calorific) value of the biodiesel was higher than that of the ASTM-02 of standard biodiesel. This could be because the seed was properly dried to reduce the moisture contents and also the extracted oil was distilled appropriately.

Table 3: Physico- chemical Properties of Avocado Biodiesel (ABD)

Properties	*Analysis Results (ABD)*	*Standard values Biodiesel (ASTM D675-02)*
Specific Gravity	0.869	0.850 − 0.890
Density @ 15℃ (kgm^{-3})	869	850 − 890
Viscosity@ 34℃(mm^2/s)	3.59461	2.3 − 6.0
Flash Point ℃,	80	< 100
Acid Value ($mgKOH/g$)	0.76	0.8
Heating Value (MJ/kg)	41.113	37 − 39

The output parameters, which show the engine performance was based on emission quality (carbon monoxide; CO, oxide of nitrogen; NO_x, particulate matter; PM), the exhaust temperatures as well as engine efficiency. Although, there are other exhaust parameters like CO_2, Hydro-carbon, etc. The software was only able to carry out the simulation of CO, NOx and PM as well as the engine efficiency and the exhaust temperature. This is probably due to the fact that the software was designed to such limits. Python plugin (for blender), used for fluid analysis was installed to help in analyzing the fuel performance in the engine. The analysis was finally run and the results are displayed in Figures 2 and3.

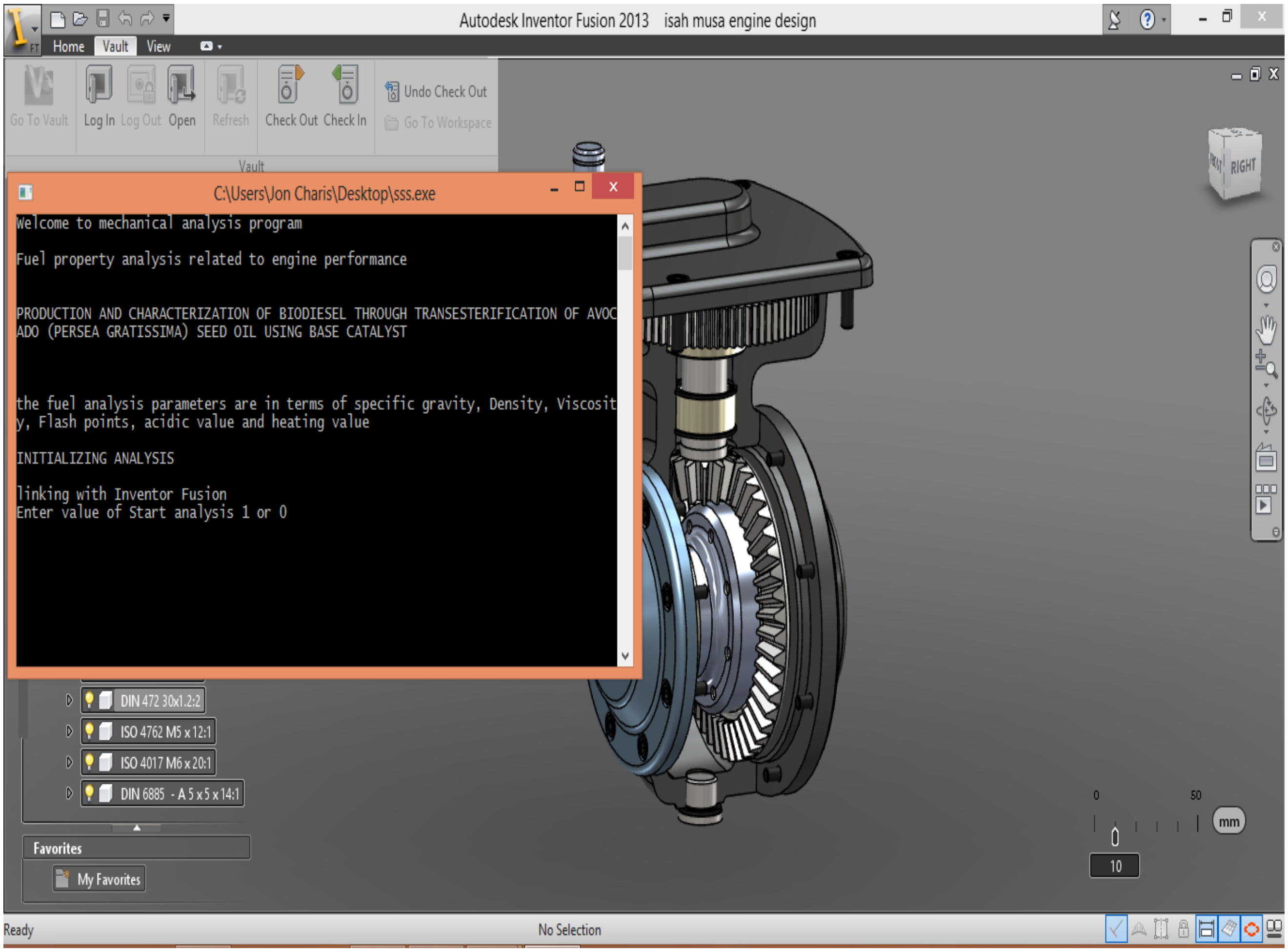

Figure 2: Initializing the analysis for running

After the analysis was run, the result was presented in Figure 3. Carbon Monoxide; CO, Oxide of Nitrogen; NO_X, Particulate Matter; PM, the exhaust temperatures as well as engine efficiency were analyzed (Figure 3 and Table 4).

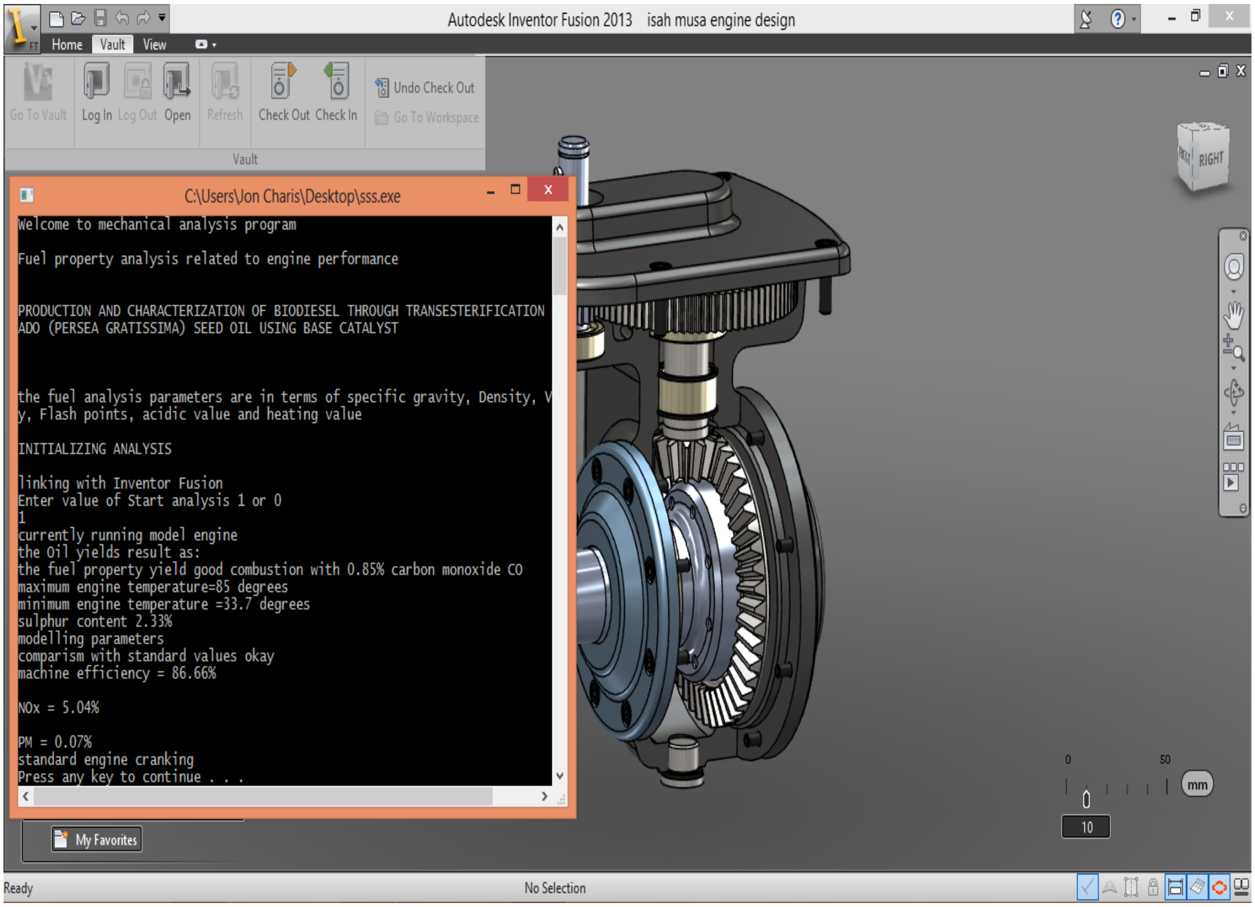

Figure 3: Result of the analysis after run

Table **4**: Correlation between the Model Results and the Conventional Fuel

Emissions	CO%	PM %	NO_x %
Analysis	0.75	0.07	5.04
Petroleum diesel	1.40	0.11	4.55

From the results of the performance analysis of the fuel, (Figures 3 and Table 4), Carbon Monoxide (CO) was found to be 0.75%, for the Avocado Biodiesel (ABD) and 1.40% for the petrol diesel. 65% reduction of CO in ABD was as a result of the higher oxygen content, which enhances a complete combustion and lower Carbon to hydrogen ratio in biodiesel compared to diesel (Jinlin*et al.*, 2011).

The Particulate Matter (PM) of the ABD of 0.07%, was found to be 4% lower than that of the petrol diesel,0.11%. This was due to the higher in oxygen content as well as lower in aromatic and sulfur compounds in biodiesel (Jinlin*et al.*, 2011).

The $No_x$of the ABD 5.04% was higher than that of the petrol diesel 4.55% by 10%. This was because of the higher oxygen contents for biodiesel. (Jinlin *et al.*, 2011).

The efficiency of the machine was determined using a BLENDER, with a python, as a plugin to the model in the inventor fusion 2013. The determinant was based on the Break Specific Fuel Consumption, and the efficiency was found to be 86.66%

CONCLUSION

It was therefore concluded from the study that:

1. The properties of the ASO determined were found to meet the (ASTM 675-02) standard.
2. Fuel properties of ABD investigated were found to meet ASTM D 675 standard.
3. The virtual biodiesel engine designed using Autodesk Inventor 2013 and the simulation of the emission qualities (CO, NO_x, PM) were found to be appropriate since the level of the observed differences were not significant.
4. The biodiesel yield gave a good emission quality and the characterization of the biodiesel: Specific Gravity ($S.G$), Density, Viscosity, Flash point, Acid value and higher heating value meet the standard of biodiesel (ASTM 675-02).

REFERENCES

Arifin, S. F. (2009*). Production of biodiesel from waste cooking oil and RBD palm oil using batch transesterification process. A thesis submitted in fulfillment of the requirements for the award of the degree of Bachelor of Chemical Engineering, Universiti Malaysia Pahang.*

Formo M.W. (2001). Ester reactions of fatty materials*. J AmOilChem Soc. 31(11): 548 59*

Ikhuoria, E.U. and Maliki, M. (2001).Characterization of Avocado Pear (Perseaamericana) and African

Pear (Dacryodesedulis) Extract.*Biotechn. 7: 950-952.*

Maitera O. N,Osemeahon S. A, Barnabas H. L (2014).Proximate and Elemental Analysis of Avocado Fruit.*A Research Article, Ind. Sci. Res. And Tech: 67-73.*

Martinez-Herrera, P. S. O.(2006). Chemical composition, toxic/antimetabolic constituents, and effects of different treatments on their levels, in four provenances of *Jatrophacurcas* L. from Mexico.*Journal of Food Chemistry , 80–89.*

Nada E. M. (2011). The Manufacture of Biodiesel from the used vegetable oil. *A thesis submitted to the Faculty of Engineering at Kassel and Cairo Universities for the degree of Master of Science,14-19.*

Oluwole, F. A., N. A. Aviara, B. Umar and H. Umar (2014). Effect of Variety and Processing Parameters on Oil Content and Oil Properties of Castor Seeds. *Continental Journal of Science. Vol. 9 (1): 36-49.*

Peter, F. and Ann, H. (1992).Small scale food processing.A guide to appropriate equipment. International Technology Publication, London.

Rachimoellah H. M., DyahAyuResti, Ali Zibbeni, dan I WayanSusila, (2009). Production ofBiodiesel through Transesterification of Avocado (Perseagratissima) Seed Oil Using Base Catalyst.*Jurnalteknikmesin vol. 11, no. 2: 85–90.*

Sivaramakrishnan K. and Ravikumar P. (2006). Performance Optimization of Karanja Biodiesel Engine Using Tagushi Approach and Multiple Regression. *Department of Mechanical Engineering India.*

www.infonetbiovision.org/default/ct/205/crops, (2015).Zhu D., H. N. (1997). Kinetics of Transestrification of Soybean Oil.JAOCS, *1457-1463.*

Chen, H., Morrell, P. L., Ashworth, V. E. T. M., De La Cruz, M. and Clegg, M. T. (2008). Tracing the Geographic Origins of Major Avocado Cultivars. *Journal of Heredity 100 (1): 56 65*.

Jinlin, X., Tony E. Grift and Alan C. Hansen (2011). Effects of Biodiesel on Engine performances and Emissions. *A Journal of Renewable and Sustainable Energy Review; 1098-1116.*

Pooja, G. and Mayur, G. (2012). Experimental Studies on Emission and PerformanceCharacteristics in Diesel Engine using Biodiesel Blends EGR (Exhaust GasRecirculation).*International Journal of Engineering Technology and Advanced Engineering. 2: 2250-2459.*

Rachimoellah H. M., DyahAyuResti, Ali Zibbeni, and Dan I WayanSusila, (2009). Production ofBiodiesel through Transesterification of Avocado (Perseagratissima) Seed Oil Using Base Catalyst.*Jurnalteknikmesin vol. 11, no. 2: 85–90.*

Sivaramakrishnan K. and Ravikumar P. (2006). Performance Optimization of Karanja BiodieselEngine Using Tagushi Approach and Multiple Regression. *Department of Mechanical Engineering India.*

Waziri I. A., Muazu K., Mohammed Dabo (2012). Development of mathematical model for the transesterification of *Jatrophacurcas* seed oil in heterogeneous catalyst, *India.*