

Biodiesel Production Based on Waste Cooking Oil (WCO)

Nor Hazwani Abdullah, Sulaiman Haji Hasan, and Nurrul Rahmah Mohd Yusoff

Faculty of Mechanical and Manufacturing Engineering , Universiti Tun Hussein Onn Malaysia, Parit Raja 86400, Batu Pahat, Johor Darul Ta'zim, Malaysia

Email: {Nshazwany, nurrul0501} @gmail.com; sulaiman@uthm.edu.my

Abstract—Recycled waste cooking oil is harmful to health, but it is not environmental friendly to dispose used cooking oil just like that. The best solution is to use it for industrial purposes, namely to reproduce into biodiesel. Waste cooking oil is collected from chip cracker Factory in Johor. This project is to produce biodiesel from waste cooking oil using pilot plant and the biodiesel tested in the laboratory. The pilot plants are continuous system to produce biodiesel. The biodiesel was blended with diesel oil to get B5 and B10 grade biodiesel. It produces biodiesel based on the American biodiesel standard ASTM6751. The application of this biodiesel has enabled the company to use its waste cooking oil without having to dispose it and this has save cost to the company. The other advantage is that it has significantly help to preserve environment and as well as conversion of waste to useful energy. The biodiesel plant has also motivated the staff towards thinking about environment and also alternative energy thus sustaining its operation.

Index Terms—Biodiesel, waste cooking oil, pilot plant, alternative energy

I. INTRODUCTION

Waste cooking oil has always been an environment problem in food factories in Batu Pahat, Johor, Malaysia. Converting the WCO into biodiesel will reduce this problem. This project will not only save environment but also cost.

II. LITERATURE REVIEW

Biodiesel is an alternative diesel fuel derived from vegetable oils or animal fats. The main components of vegetable oils and animal fats are triglycerides or also known as ester of fatty acid attached to glycerol. One of the main driving force for biodiesel widespread is the greenhouse gas emission (CO₂ being the major one). The term waste cooking oil (WCO) refers to vegetable oil has been in food production and which is no longer viable for its intended use. WCO arises from many different sources, including domestic, commercial and industrial. WCO is a potentially problematic waste stream which requires proper management. The disposal of WCO can be problematic when disposed incorrectly.

Any fatty acid sources may be used to produce biodiesel. Therefore, any animal or plant lipid should be ready substrate for the production of biodiesel. The use of edible vegetable oils and animal fats for biodiesel production has recently been of great concern because they compete with food material- the food versus fuel dispute. There are concern that biodiesel feedstock may compete with food supply in the long term. From an economic point of view; the production of biodiesel is very feedstock sensitive. The cost of feedstock accounted for 88% of total estimated production cost. In all cases, more than 80% of the production cost is associated with the feedstock, such as recycled cooking oils. Reusing of these waste greases not only reduce the burden of the government in disposing the waste, maintaining public sewers, and treating the oily wastewater, but also lower the production cost of biodiesel significantly.

This project is aimed to develop a simple small plant to process the waste cooking oil to biodiesel and use it in the factory.[1] [2]

A. Feedstock Waste Cooking Oil

Biodiesel can be produced from any material that contains fatty acids, be they linked to other molecules or present as free fatty acids. Thus various vegetable fats and oils, animal fats, waste greases, and edible oil processing wastes can be used as feed stocks for biodiesel production. The choice of feedstock is based on such variables as local availability, cost, government support and performance as a fuel. The primary feedstock is a vegetable oil or animal fat, biodiesel is generally considered to be renewable. Since the carbon in the oil or fat originated mostly from carbon dioxide in the air, biodiesel is considered to contribute much less to global warming than fossil fuels. Diesel engines operated on biodiesel have lower emissions of carbon monoxide, unburned hydrocarbons, particulate matter, and air toxics than when operated on petroleum-based diesel fuel [3].

In 2008, Malaysia produced 17.7 million tones of palm oil on 4.5 million hectares of land, [4] and was the second largest producer of palm oil, is employed more than 570,000 people [5]. Malaysia is the largest exporter of palm oil in the world. About 40% of palm oil mostly made into cooking oil, margarine, specialty fats and oleochemicals [4]. Most cooking oil are made from palm oil. In the fast food business alone, a single branch which

Manuscript received November 15, 2013; revised December 15, 2013.

serves fried food such as fried chicken, french fries and burgers can produce as much as 15 liters of used cooking oil per day. Considering that there are hundreds of these outlets in Malaysia, the total amount generated can reach several thousand liters per day. Properties of degraded used cooking oil after it gets into sewage system are conducive to corrosion of metal and it also affects installations in waste water treatment plants. Thus, it adds to the cost of treating effluent or pollutes waterways [5]. Waste cooking oil is one of the alternatives for biodiesel process.

Biodiesel from waste cooking oil (WCO) can reduce the cost of biodiesel production since the feedstock costs constitutes approximately 70-95% of the overall cost of biodiesel production [6]. Although biodiesel cannot entirely replace petroleum-based diesel fuel, there are at least five reasons that justify its development.

- It provides a market for excess production of vegetable oils and animal fats.
- It decreases, although will not eliminate, the country's dependence on imported petroleum.
- Biodiesel is renewable and does not contribute to global warming due to its closed carbon cycle. A life cycle analysis of biodiesel showed that overall CO₂ emissions were reduced by 78% compared with petroleum-based diesel fuel [7].
- The exhaust emissions of carbon monoxide, unburned hydrocarbons, and particulate emissions from biodiesel are lower than with regular diesel fuel. Unfortunately, most emissions tests have shown a slight increase in oxides of nitrogen (NO_x). When added to regular diesel fuel in an amount equal to 1–2%, it can convert fuel with poor lubricating properties, such as modern ultra-low-sulfur diesel fuel, into an acceptable fuel.

III. METHODOLOGY

Fig. 1 describes the steps, processes and methods used to produce biodiesel product. This process started from free fatty acid to determine acid value and step of process. Second process is drying to remove water in FAME and last process is properties physical to determine contents of FAME.

A. Feedstock Waste Cooking Oil

Based on Fig. 1 it is recognized that the production of waste cooking oil will be the function of the frying temperature and length of use as well as the material used for frying. In this experiment, WCO were collected from a local Factory (Azhar Food Sdn Bhd) in Johor, which produced chip cracker as well as continental foods. The used oil sample was taken from the fryer which is used for frying potatoes and other vegetables based food items. Twenty-five liters of oil samples were collected from a collecting drum in which the waste cooking oil was collected once in every days for approximately 1 weeks. The oil sample is assumed to be representative as it is collected from the oil stored for 8-10 weeks from several batches of waste oil. The temperature observed during frying was in the range of 130°C to 175°C. This

temperature is comparable with the temperature (140°C-180°C) for preparing French fries [8]. However, it was found difficult to read the temperature in boiling oil which gives approximately 5-10% error. Depending on the quantity of food used for frying, the oil was discarded sometimes at the end of each day and sometimes once in two or three days.

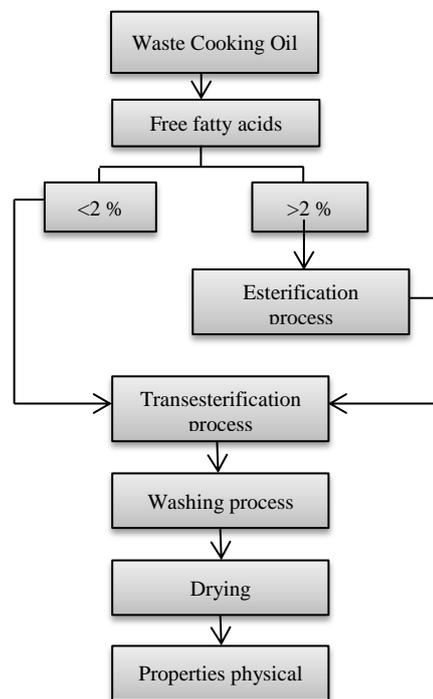


Figure 1. Flow Chart to Produce Biodiesel from WCO

B. Free Fatty Acids

Flow chart in Fig. 1 shows the relation between FFA and process. Which FFA less than 2%, the process can directly to transesterification process and while FFA more than 2% it need to start from esterification process to reduce FFA. The acid value of the waste cooking oil was determined in order to estimate the free fatty acid content and give an idea of how much acid catalyst and methanol would be needed to push the acid esterification chemical towards methyl ester production. In earlier published research it was recommended that 0.5 - 1.5% (based on the weight of free fatty acid in the oil) of pure (95-98%) sulphuric acid should be used as a catalyst. Acid value titration method was used according to BP monograph [9].

C. Processing in Biodiesel

Biodiesel has two main stage process is esterification and transesterification process. Separation was used to separate two layer between catalyze and oil. Washing process to produce the neutral biodiesel and remove catalyzes glycerol, soap and methanol.

1) Esterification

Based on flow chart in Fig. 1 esterification is one of process in biodiesel. It work to reduce FFA if FFA more than 2%. An acid-catalyzed esterification process before the base-catalyzed transesterification process will

eliminate most of the free fatty acids from the vegetable oil. Sulphuric acid (95 – 98%) is used by 1% in esterification process depend from waste cooking. In these experiments the sulphuric acid was first mixed with methanol before adding to the waste cooking oil. After adding the methanol / sulphuric acid and waste cooking oil the agitator speed were used to mix the solvents until they became murky. This was then heated to about 60 °C for 2 hours. A higher temperature or a faster stirring rate may push the acidic esterification equation to convert free fatty acid to methyl ester. [9]

2) Separation 1

Separation needed 3hour to get the top methanol and bottom oil layers of the biodiesel. Two layers could clearly be seen in the successful basic esterification biodiesel. The top layer was mainly methanol. The bottom layer was mainly triglyceride product esterification after remove the water. These processes to reduce free fatty acid until below 2%. The density of the methanol is less than the bottom triglyceride.

3) Transesterification

Transesterification process work as to reduce viscosity in biodiesel. This process can be directly if FFA less than 2% show in fig. 1. Sodium hydroxide was used as catalyst in this process. The amount of catalyst had an impact in the conversion of esters during the transesterification process. The reaction was carried out using 1% of catalyst concentration. Before transesterification process Sodium hydroxide was first mixed with methanol together in one container before adding to the waste cooking oil. After adding the methanol / sodium hydroxide and waste cooking oil the agitator speed were used to mix the solvents until they became murky. This was then heated to about 60 °C for 2 hours.[9]

4) Separation 2

Transesterification process and any methanol evaporation the resultant biodiesels were left to lie for at least 8 hours. Separations were used to separate the top (methyl ester) and bottom (glycerol) layers of the biodiesel samples. Two layers could clearly be seen in the successful basic transesterification biodiesel samples. The top layer was mainly composed of free fatty acid methyl esters. The bottom deposit was mostly made up of glycerol, salts, soap, other impurities and excess methanol as it is a very polar compound i.e. it partitions more with polar glycerol as opposed to the non-polar methyl esters.

5) Washing

The top methyl ester layer was separated and removed from every production sample. The water washing process was then used on some of the biodiesel batches. Once separated from the glycerin the biodiesel is sometimes purified by washing gently with warm water to remove residual catalyst or soaps, dried, and sent to storage. In some processes this step is unnecessary. This is normally the end of the production process resulting in a clear amber-yellow liquid with a viscosity similar to

petrodiesel. In some systems the biodiesel is distilled in an additional step to remove small amounts of color bodies to produce a colorless biodiesel. [9]

IV. RESULT AND DISCUSSION

A. Esterification Process

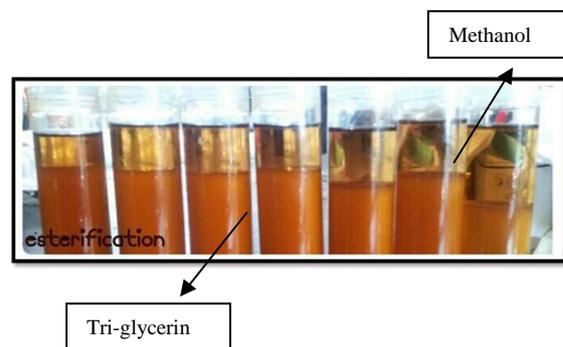


Figure 2. Esterification process result

- Fig. 2 shows the separation between methanol and triglycerin.
- At the top will be presence methanol and at the bottom show triglycerin.
- Involves the reaction of alcohol (such as methanol) with fatty acids as catalyzed
- to reduce the levels of FFA in the low-cost feedstocks to an acceptable range
- Reaction between acids and alcohols in the presence of strong acid catalyst
- Produce ester and water
- free fatty acid of material must be less than 2%

It needs to use methanol and Sodium Hydroxide as catalyst

- Fig. 3 show two layer separation between glycerol and FAME
- At the top will be presence FAME and the at bottom is glycerol
- Reduce the high viscosity of triglyceride (TG)
- methanol and catalyst produce methyl ester and glycerol
- involves the reaction of alcohol (methanol) with oil

B. Transesterification Process

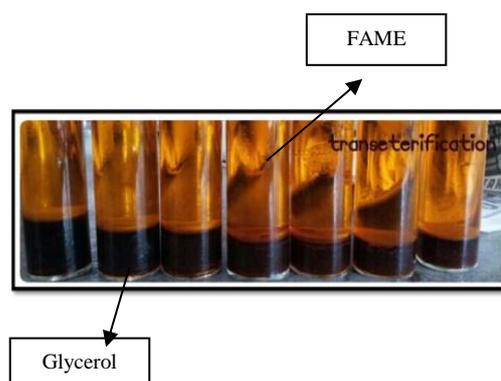


Figure 3. Transesterification process result

C. Washing & Distillation Process

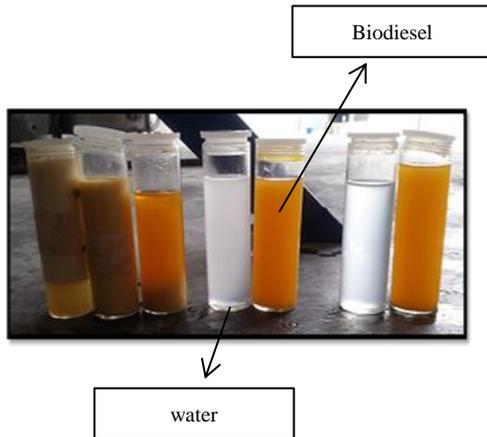


Figure 4. Washing & distillation process result

Fig. 4 shows separation between water and FAME.

- to remove small amounts of colour bodies to produce a colourless biodiesel it need washing many time
- To obtain pure methyl esters (Biodiesel/ FAME)
- To remove soap, catalyst, methanol and other pollutants of biodiesel, using water
- If the washing is not complete, it will be repeated by esterification and transesterification or washing.

D. Biodiesel

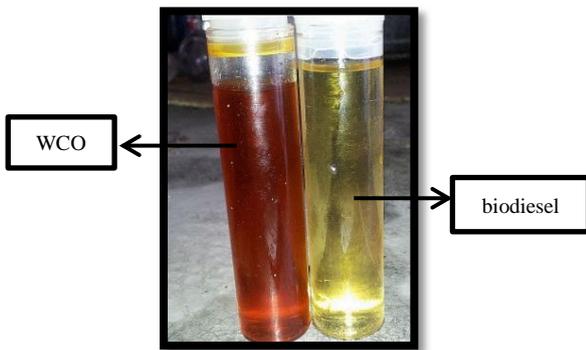


Figure 5. WCO to biodiesel

- Biodiesel can show in fig. 5 which left is raw material and right is biodiesel.
- The percentage of biodiesel around 68-70% can be produce.
- Increase in the molar ratio the conversion of WCO to FAME decrease.
- At the same time, the waste can be converted to useable energy, pollution due to waste cooking oil can be avoided, and energy can be continuously saved and renewed.

E. Drying

After washing water still have inside biodiesel. Fig. 6 show oven for drying biodiesel. Then the water must be removed from the biodiesel using drying at 120°C for 24 hour.



Figure 6. Drying Biodiesel

F. Physical Properties

Properties are one of method to determine the standard of biodiesel. Biodiesel can check using density, viscosity, flash point, acid value and water content.

1) Density

Fig. 7 shows how to measure density using pycnometer. The density of biodiesel at 15°C was found to be 87 g/cm³ that density is a function of temperature and decreased linearly for canola methyl esters, soy methyl esters, and fish oil ethyl esters by 1.23 kg/m³ °C for temperatures between 20–300°C.[10]

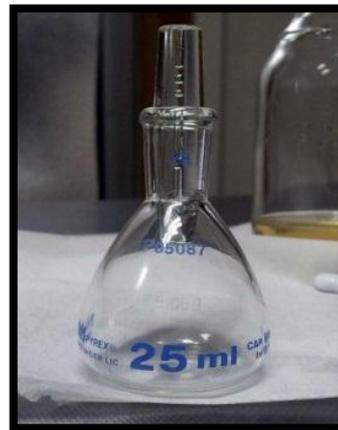


Figure 7. Pycnometer

Fig. 8 is equipment for testing kinematic viscosity and Standard method for kinematic viscosity is ASTM D 445 – Kinematic viscosity, 40 °C, requirement: 1.9 – 6.0 mm²/s. Kinematic viscosity: “the resistance to flow of a fluid under gravity”. The kinematic viscosity is equal to the dynamic viscosity/density the kinematic viscosity is a basic design specification for the fuel injectors used in diesel engines. Too high a viscosity and the injectors do not perform properly. Dynamic viscosity – ‘ratio between applied shear stress and rate of shear of a liquid.’ Density – “the mass per unit volume of a substance at a given temperature.” The viscosity of biodiesel can be predicted ± 15 % using the esters composition determined using ASTM D 6584. The viscosity apparatus to run D 445 is not critical to the QC laboratory, but it is valuable as a quick assay method for estimating the degree of completion for a reaction batch [11].

2) *Kinematic viscosity*



Figure 8. Equipment for kinematic viscosity

3) *Flash point*



Figure 9. Equipment for flash point

Fig. 9 show the equipment for testing combustion in biodiesel using method ASTM D93- Flash point, closed cup, requirement 130 °C min. The flash point is defined as the “lowest temperature corrected to a barometric pressure of 101.3kPa (760 mm Hg), at which application of an ignition source causes the vapors of a specimen to ignite under specified conditions of test.” [11]

4) *Asid number*



Figure 10. Purple color is indicator to show the acid number

Fig. 10 is testing for asid value using method ASTM D 664 – Acid number, requirement 0.80 mg KOH/g. The

acid number is “The quantity of base, expressed as milligrams of potassium hydroxide per gram of sample, required to titrate a sample to a specified end point.” The acid number is a direct measure of free fatty acids in B100. The free fatty acids can lead to corrosion and may be a symptom of water in the fuel. Usually, for a base catalyzed process, the acid value after production will be low since the base catalyst will strip the available free fatty acids. However, the acid value may increase with time as the fuel degrades due to contact with air or water. This test should be performed regularly as a part of the producer QC program [11].

5) *Water content*



Figure 11. Equipment for test water content

Fig. 11 shows the testing of water content. This testing is very important in biodiesel. Before biodiesel are use in the engine water content must be follow the standard to avoid damage. The standard ASTM method D2709 is max 0.005%.

V. SUMMARY

The biodiesel was prepared from waste cooking oil sample collected from a local factory in Malaysia. The biodiesel was characterized for its physical and fuel properties using ASTM standard methods for biodiesel fuel quality assurance The composition of final biodiesel was determined by physical properties such as density, viscosity, flash point, water content and acid value. From the tests, the flash point was found to be 97°C, water and sediment was 0.02%, total acid number was 0.29 mgKOH/g, viscosity at 40°C was 4.2 mm²/sec and density 0.82g/cm. Out of 5 properties tested, all of them met the ASTM criteria for fuel standard. Production of biodiesel from waste cooking oils for diesel substitute is particularly important because the increasing cost of oil extracted from petroleum source and also it is good for enviroment. Waste cooking oil can be an important source for biodiesel production in Malaysia it is ready available and environment.

ACKNOWLEDGMENT

A special thanks goes to my supervisor Prof.Dr. Sulaiman Haji Hasan, for the biodiesel project and thank you to all the assistance from technicians and staff of UTHM and Azhar Food Sdn Bhd.

REFERENCES

- [1] B. K. Barnwal and M. P. Sharma, "Prospects of biodiesel production from vegetable oils in India," *Renewable Sustainable Energy Review*, vol. 9, no. 4, pp. 363-378, 2005.
- [2] M. F. Demirbas and M. Balat, "Recent advances on the production and utilization trend of biofuels: A global perspective," *Energy Conversion and Management*, vol. 47, pp. 2371-2381, 2006.
- [3] WIKIPERIA: Biofuel. [Online]. Available: <http://wikipedia.org/wiki/Biofuel>
- [4] M. Szmigielski, *et al.*, "Evaluation of chosen quality parameters of used frying rape oil as fuel biocomponent," *Int. Agrophys*, vol. 22, no. 4, pp. 361-364, 2008.
- [5] A. B. Chhetri, *et al.*, "Waste cooking oil as an alternate feedstock for biodiesel production," *Energies*, vol. 1, pp. 3-18, 2008.
- [6] S. John, *et al.*, *Life Cycle Inventory of Biodiesel and Petroleum Diesel for use in an Urban Bus*, Final Report for U.S. Dept. of Energy's Office of Fuel Development and the U.S. Dept. of Agriculture's Office of Energy, The National Renewable Energy Laboratory, NREL/ SR-580-24089, May 1998.
- [7] B. K. Barnwal and M. P. Sharma, "Prospects of biodiesel production from vegetable oils in India," *Renewable and Sustainable Energy Reviews*, vol. 9, no. 4, pp. 363-378, 2005.
- [8] S. Zheng, M. Kates, M. A. Dube, and D. D. McLean, "Acid-catalyzed production of biodiesel from waste frying oil," *Biomass & Bioenergy*, vol. 30, no. 3, pp. 267-272, 2006.
- [9] X. Chen *et al.*, "Optimisation of the conversion of waste cooking oil into biodiesel," Strathclyde Institute of Pharmacy and Biomedical Sciences, University of Strathclyde, The John Arbuthnott Building, 27 Taylor Street, Glasgow, G4 0NR, Scotland.
- [10] R. E. Tate *et al.*, "The densities of three biodiesel fuels at temperatures up to 300oC," *Fuel*, vol. 85, pp. 1004-1009, 2006.
- [11] J. Van Gerpen, "Biodiesel production technology," Iowa State University, D. Clements Renewable Products Development Laboratory, G. Knothe USDA/NCAU, pp. 22-26, 2004.



Nor Hazwani Binti Abdullah was born on 18 April 1987 in Kuala Lumpur, Malaysia. She obtained her Bachelor of Mechanical and Manufacturing Engineering from University Tun Hussien Onn Malaysia and Diploma in Mechatronic Engineering from Polytechnic Sultan Azlan Shah Malaysia.



Sulaiman haji Hassan is a Professor of Manufacturing Engineering at University Tun Hussein Onn Malaysia, Batu Pahat, Johor. He passes diploma of education from university Malaya and MSc in Advance Manufacturing at University Liverpool, United Kingdom in 1987. He then did Doctor of philosophy awarded by University Birmingham, United Kingdom in 1997. His career with University Tun Hussein Onn Malaysia started in 2001 as a Dean of Faculty Engineering Technology and continued as Director at International Relation from 2003 until 2006. He then become the Dean of Mechanical and Manufacturing Engineering from 2006 to 2011. Some of his later paper Deep Cryogenic Treatment On Aluminum Silicon Carbide Composite, Investigation On Surface Integrity On 420 Martensitic Stainless Steel By Cryogenically Treated Steel Balls With Low Plastic Burnishing Tools, Performance On Deep Cryogenically Treated And Non-Treated Inserts In Milling and he has 37 journal paper and his main research group is Advanced Manufacturing and Material Centre.