Jurnal
Teknologi

Full Paper

BIODIESEL PRODUCTION FROM WASTE FISH FOR ZERO WASTE CONCEPT IN REMOTE AREA OF EASTERN OF JAVA, INDONESIA

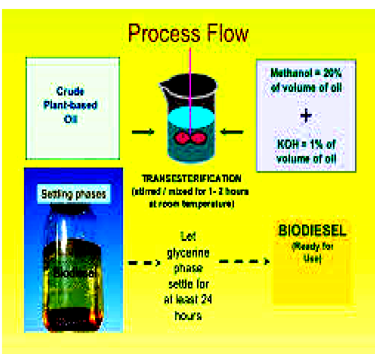
Article history
Received
7 January 2016
Received in revised form
19 February 2016
Accepted
24 February 2016

Soni Sisbudi Harsono[a*], Roy Hendroko Setyobudi[b,c], T. Zeemani[d]

[a]Department of Agricultural Engineering University of Jember Faculty of Agricultural Technology (UNEJ) Jl. Kalimantan 23 Jember 68121, East Java, Indonesia
[b]Indonesian Asscosiation of Bioenergy Scientist, BPPT Building II, 22nd Floor Jl. MH Thamrin No. 8 Jakarta 10340, Indonesia
[c]Ma Chung Research Center for Photosynthetic Pigments, Villa Puncak Tidar N-01 Malang 65151, East Java, Indonesia
[d]Department of Production Engineering, Faculty of Engineering, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 94976, Slovak Republic

*Corresponding author:
s_harsono@yahoo.com

Graphical abstract



Abstract

Increasing demand fossil fuel in the world may have a good impact on biodiesel demand. Other than produced from plant oil, biodiesel can also be produced from waste fish and fish wastes. Extracted oil from both of fish waste may be turned into biodiesel to be used for ship's diesel engine or other purposes. The objective of this study is to analyze the energetic efficiency in the production of fish wastes as feedstock for the production of biodiesel in Indonesia. The biodiesel production chain is analyzed to quantify the net yield of energy and exergy and their respective degree of efficiency. The energy consumption calculation for the biodiesel production system is assessed as the sum of energy consumption in different stages in its production chain. Energy efficiency in biodiesel production can be assessed using an index for technical, economic and environmental sustainability analysis. The fish oil was separated from fish wastes using a specially designed oil extraction machine. Both direct and indirect energy and exergy flows are important parameters for evaluating the energetic efficiency of biodiesel. Further, the analysis shows that it is necessary to find ways to improve the exergy efficiency without decreasing the energy efficiency during production of biodiesel from waste fish.

Keywords: Biodiesel, fish oil, exergy, energy efficiency, waste fish

1.0 INTRODUCTION

Two-thirds of Indonesia is water. Therefore fish production potential is quite huge. As easily perishable product, fish processing often highly wasteful. Fish waste may result during various stage of production, started from the bad catching practices, during transportation dan pre production. For illustration purposes, the waste fish volume in East Java areas reached 50 t to 60 t per mo. Currently there is no economic utilisation of this resource, although It can be utilizeed as into biodiesel [1]. The biodiesel used to improve quality of octane and reduce greenhouse gas emissions [2]. Diesel was first produced from peanut oil. However, when industrial revolution was started, continued by the first world war, diesel fuel need was increased many fold. The production of peanut based diesel could not keep up with the demands. As a result, vegetable fuel oil was replaced with petroleum based diesel. Especially than it increasingly realize how increasingly limited oil resources are non-renewable [3]. Many years later the world realised that consuming fossil fuel came with with accompanying environmental costs, as well as cost the next generations of their availability. Biodiesel was thus received new interests [4].

Being a country with large sea area and coasts, Indonesia has large fish potential. Unfortunately, this fish potential has not been thoroughly utilised [5]. As houholds consumption, fishes has been only consumed for their meat, while other parts of the fish (such as fish entrails, heads and bones) are usuallly thrown away as wastes. In the area of the fish auction locations waste fish are often produced from fishes which are caught but not economic to be sold (or utilized). Given proper process, such wastes (waste fish as well as fish wastes) has the potential to be processed into fuel [6] as can be seen in Figure 1.

Turning waste fish and fish waste into biodiesel is started with production of fish oil (waste fish and fish wastes are firstly crushed, then cooked and oil is separated from the remaining of fish waste) [7]. After fish oil is produced, it then put into a chemical process called transesterification, namely the separation of glycerin from animal oils with the help of a strong hydroxide (NaOH) as a catalyst. The resultant product is biodiesel (methyl ester), the chemical name of biodiesel, and glicerin [8] as written in Table 1.

Table 1 Fatty acids in fish oil

Fatty acid Saturated	Ammount (%)	Unsaturated Fatty Acids	Ammount (%)
Palmitic acid(C16:0)	13.3	Oleic acid (C18:1)	25.2
Stearic acid (C18:0)	2.9	Linoleic acid (C18:2)	2.3
		Linolenic acid (C18:3)	0.4
		Stearidonic acid (C18:4)	1.4
		Eicosenoic acid (C20:1)	9.2
		Arachidonic acid (C20:4)	3.1
		Eicosapentaenoic acid EPA (C20:5)	9.2
		Erucic acid (C22:1)	6.6
		Diesel particulate filter additives (DPA: C22:5)	3.4
		Diesel particulate filter additives (DPA: C22:6)	7.3

Sources: [1]

Sources: [2]

Figure 1 Fish processing in a costal Eastern Java Sea

The aim of this study is three folds. Firstly, to document the influence of various mole ratio between the fish oil with methanol on the transesterification reactions using microwave radiation; secondly to determine the effect of raditation on transterifiation process; and thirdly to identify compounds contained in biodiesel produced from fish oil conversion.

There will be several benefit resulted form this research. First, this research will decrease negative environment impact resulting from rotten waste fish, secondly, the research should promote the use of waste fish and fishwaste as biodiesel.

2.0 MATERIAL AND METHOD

This research was conducted in a remote island of Eastern of Java (Indonesia). Biodiesel production from fish waste can be divided into four stages, namely the fish oil filtering and esterification, determiation of acid numbers, transesterification with microwave radiation, and finally biodiesel washing and purification. Oil filtering is done to remove large particles or impurities contained in fish oil. To do this, fish oil is preheated to a temperature of (30 to 35) °C and then filtered using a coffee filter.

Esterification is conducted when filtered oil is heated to 45 °C and then added methanol and catalyst (H_2SO_4 0.5 wt % of fish oil by volume and 30 % of methanol by oil volume). The mixture is then refluxed at a temperature of 52 °C for 1 h. To obtain a neutral pH mixture, H_2SO_4 is neutralized by washing the mixture using distilled water repeatedly until a neutral pH is reached as can be seen in Figure 2a. Esterification is checked before and after the acid number.

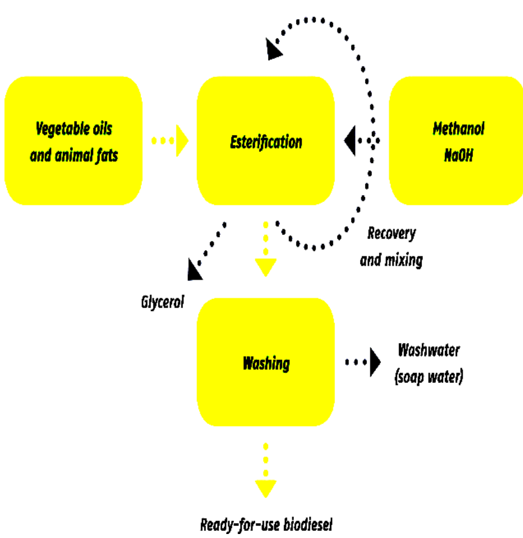


Figure 2a Biodiesel production stages

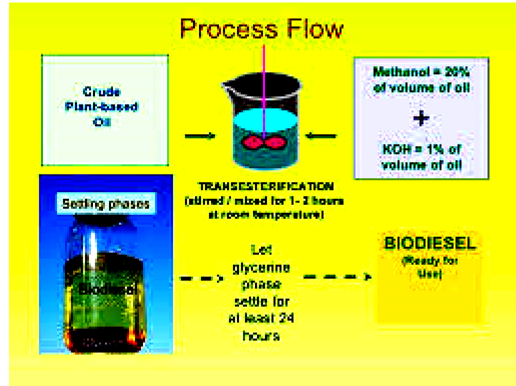


Figure 2b Biodiesel production from fish waste

2.1 Determination of Acid Numbers

An erlenmeyer 1 mL oil plus two drops of phenolphthalein indicator, then the mixture is titrated with 0.005 N KOH to produce a pink color.

2.2 Transesterification with Microwave Radiation

Catalyst, in the form of NaOH at 1 % of oil volume, is required for transesterification process. The resultant transesterification process consists of free oil and water plus methanol in such ratio that it has a mole ratio of 6:1; 12:1; 18:1; 24:1 (methanol to fish oil ratio). $NaOCH_3$ is then added in the mixture, and the new mixture is stirred for 10 min. This stirred mixture is then treated by microwave radiation at power variations (300, 400, 500, 650, and 800) W and a reaction time of (5, 10, 15, 20 and 25) min to see the optimum mole and power variation as can be seen in Figure 2b. Transesterification reaction is stopped using H_2SO_4 0.1 M as a neutralizer.

2.3 Biodiesel Washing and Purification

The resulted transesterification is then added H_2SO_4 to reach pH 4 level. To determinate the methyl ester acidity, universal pH is used. To remove glycerol and soap, biodiesel is washed repeatedly using distilled water. To remove water and methanol which may still contained in the biodiesel, N2 gas and heat process is used. To obtain pure biodiesel, anhydrous Na_2SO_4 is added to remove remaining water.

3.0 RESULTS AND DISCUSSION

3.1 Biodiesel Production

The waste fish and fish waste was obtained from a fish processing plant in Banyuwangi, East Java, Indonesia. There are two types of wastes which can be used (to extract fish oil) for biodiesel production, namely the solid waste and waste water.

To extract fish oil from solid waste, it was first washed and cleaned and steamed in a temperature of 105 °C for 30 min. The steamed fish waste was then pressed to extract the oil. The pressing produces oil and water mixture and solid waste. Oil and water are then separated using a separating funnel.

For fish processing's wastewater, fish oil can be obtained by evaporation process to remove moisture. The produced fish oil (by both process) may then be used as raw material for biodiesel production.

To remove particles that are large and or impurities contained in fish oil, the raw fish oil is filtered, after heated to a temperature of (30 to 35) °C. During esterification stage, the filtered oil is further heatede to 45 °C, before added with methanol and H_2SO (H_2SO_4 0.5 wt % oil by volume, and of 30 % methanol oil volume).

Refluxing is then done to the mixture at a temperature of 52 °C for 1 h. H_2SO_4 neutralization is conducted by washing with distilled water repeatedly until a neutral pH is reacherd. Before and after checking esterification acid number, as much as 1 mL Erlenmeyer fish oil in phenolphthalein indicator is added. The mixture is then titrated with 0.005 N KOH to produce a pink color.

In the subsequent transesterification process, oil from the esterification reaction is poured into a three-neck flask, and heated to 70 °C. NaOH catalyst (solids) of 0.5 %, 1 %, 1.5 % and 2 % of the total weight of the oil and methanol (dissolved beforehand using a stirrer) is then added. The produced solution (sodium methanolic) are mixed into the oil that has been heated. Temperature was kept at at 70 °C for 2 h for reaction to occur. Stirrer was used thruout the process to stabilise the mixture. After 2 h process, the mixture is separated to produce methyl esters, water, solid soap, and other by-products using a separating funnel in order to obtain pure biodiesel.

3.2 Biodiesel Use Impact to Engine Performance

Biodiesel may have impact on engine performance. The impact includes fuel consumption, heat, emission and overall performance of the engine. Figure 3 and Figure 4 show engine performance curve (torque and power VS engine speed) as the function of biodiesel – petro-diesel blend composition. As shown in Figure 3, the peak power was reached at speed of 70 km h^{-1}. The highest peak power of 67 kW was reached by the pure petro-diesel fuel which is commercially sold at public fuel pump stations B0(2), followed by the high quality low sulphur pure petro-diesel fuel B0(1) at around 62 kW. The lowest peak power of 56 kW was produced by pure biodiesel B100. The result demonstrates that power exerted by pure biodiesel (B100) was lower than those by pure petro-diesel, both B0(1) and B0(2) in all speed levels and is considered as acceptable, as the pure biodiesel calorie content is about 10 % less than that of pure petro-diesel fuel.

The figure also shows that the B10, B20, B30 and B50 biodiesel blend gave higher power than the B0(1). This result was contradictive with the author's previous study which showed that (owing to palm biodiesel lower viscosity compare to the tested petro-diesel fuel), the study showed that power and torque for biodiesel blends was higher than pure biodiesel (B100) but lower than pure petro-diesel fuel (B0).

Therefore, it may be assumed that the higher power of the fuel blend (compared to the power of pure petro-diesel fuel in this study) could be resulted from the lower viscosity value of tested pure biodiesel B100 than viscosity value of tested pure petro-diesel fuel. It may be so, as fuel viscosity has impacts on injection and combustion. The higher the fuel viscosity, the injection pump will be harder to supply sufficient fuel to fill the pumping chamber, therefore resulted in power loss for the engine [3].

Fuel consumption of B100 (0.69 L per 10 km) was higher than fuel consumption of B0(2) (0.65 L per 10 km), but lower than B0(1) (1.03 L per 10 km). However, the CO and HC emission of B0(2) was higher than B100, while B0(2) released lower CO_2 emission than B10. Figure 2b shows that the reduction of fuel consumption as a function of biodiesel blend composition B10, B20, B30, B50 and B100 are 6 %, 9 %, 16 %, 22 % and 33 % respectively. Those result were clearly shows a close relationship between fuel viscosity and atomization. Higher viscosity of the fuel tends to reduce the quality of fuel atomization, which could potentially give negative impacts in the form of higher emission and fuel consumption. The effect of biodiesel on the reduction of exhaust gas emission is shown in Figure 4.

The figure demonstrates that the exhaust gas emission decreased linearly with the increasing concentration of the biodiesel blend. The reduction in particle and HC emission was swifter than other emissions. Particle emission was found to decrease sharply on 10 % blend of the biodiesel (B10), while the reduction of HC emission started to reduce sharply on 20 % biodiesel blend (B20).

The distinct influence of sulphur content in diesel fuel on particulate emissions has been investigated [9]. As expected, their result showed that the highest PM emission was obtained at the highest sulphur content in diesel fuel. The reduction of PM emission is depend on the value of sulphur content in the fuel. For fuel with lower sulphur (350 mg L^{-1} and 50 mg L^{-1}) content almost the same PM emission level, but for fuel with higher sulphur (2 000 mg L^{-1}) content about 20 % higher PM emission than lower sulphur diesel fuel. B0(2) has higher sulphur content (1 479 mg L^{-1}) than B0(1) (335 mg L^{-1}), but as showed on Figure 4, PM emission of B0(2) was lower than B0(1). This slightly contradictive result demonstrated that the lower viscosity value of B0(2) (4.425 cSt) (1 cSt = 10^{-6} m^2/s) than the viscosity value of B0(1) (5.436 cSt) is more effective to the reduction of PM emission compare to the effect of lower sulphur content value.

CO and NOx emissions were also reduced although not as sharp as the reduction of particle and HC emission. Lower NOx emission at higher biodiesel blend concentration is contradictive with those generally found in previous non palm biodiesel studies.

The formation of NOx depends on the combustion temperature and oxygen content in the mixing combustion product. Biodiesel blend fuel has a faster ignition ability, increase the combustion room temperature and pressure, which would finally stimulate the NOx formation. Nearly all cited studies report that biodiesel-fuelled engine has a slight increase of NOx

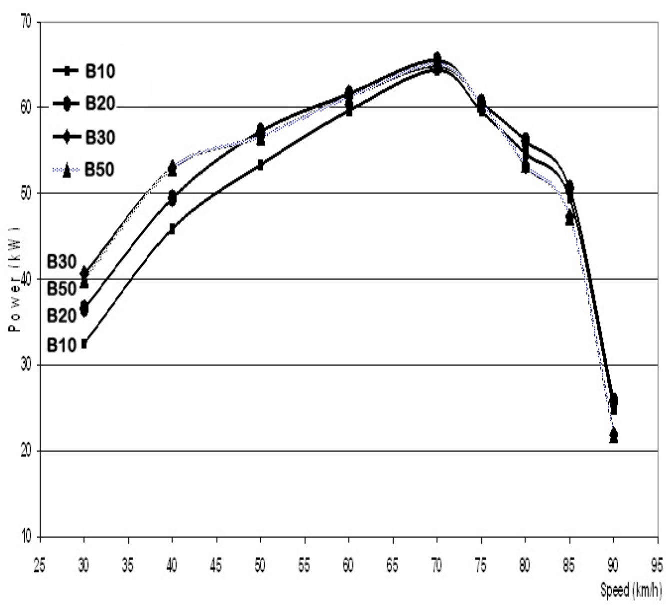


Figure 3 Power versus Speed

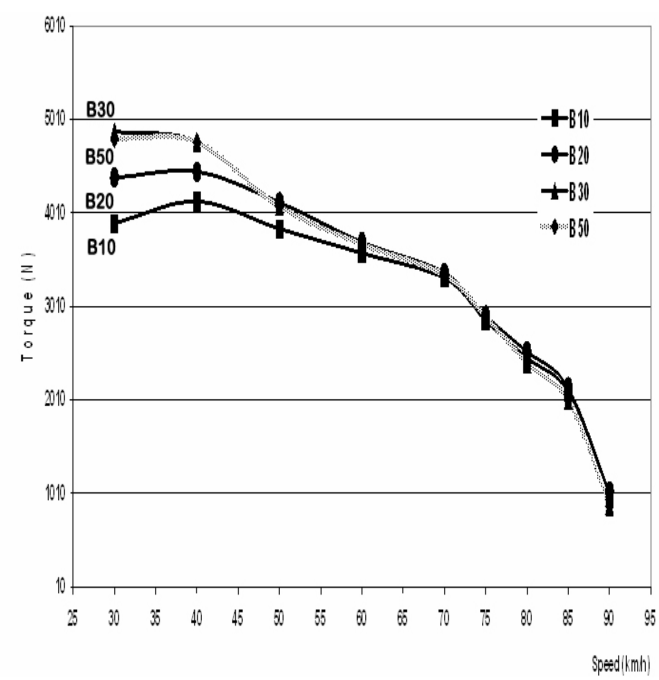


Figure 4 Torque versus Speed

4.0 CONCLUSION

Biodiesel is a renewable, biodegradable, non-toxic, and environmentally friendly fuel.Fish waste and waste fish are potential to be used as biodiesel's raw material, complementing plant oil. Fish waste may be processed to produce the fish oil as a potential alternative source of raw material of biodiesel production in Indonesia. Waste fish from the fish processing industry in the study area is huge, their utilisation is therefore help to decrease environmental pollution and waste. The use of biodiesel may also help the environment by reducing greenhoouse gas emissions. The remaining fish biomass (in cooked form) left after the fish oil is extracted can be further reprocessed to produce fish feed. In this way, fish can be utilised to produce zero waste.

Acknowledgment

The authors grateful for the Ministry of Research Technology and Higher Educaton of the Republic of Indonesia to support this researh and Faculty of Agricultural Technology, University of Jember (UNEJ) in East Java, Indonesia for obtaining permission to conduct this research.

References

[1] Astawan, M. 2003. *Ikan Air Tawar, Kaya Protein dan Vitamin* [Freshwater Fish, Rich in Protein and Vitamins]. Jakarta. [Bahasa Indonesia].

[2] Witoyo, L. 2014. *Daun Biduri Sebagai Bahan Bumbu Dapur* [Biduri Leaf for Ingredian]. Research Report. Universitas Jember [Bahasa Indonesia].

[3] Hendartomo, T. 2006. *Pemanfaatan Minyak dari Tumbuhan untuk Pembuatan Biodiesel* [Utilization of Plant Oil to Biodiesel]. Yogyakarta [Bahasa Indonesia].

[4] Darnoko, D. and M. Cheriyan. 2000. *Kinetic of Palm Oil Transesterifiation in a Batch Reactor.* Department of Food Science and Human Nutrition, University of Illinois, USA.

[5] Mashad, H., Z. Ruiphong, J. Roberto, and R. Avena. 2008. A Two Step Process for Biodiesel from Salmon Oil. *Biosystem Engineering*. 99: 220–227.

[6] Azcan, N. and A. Danishman. 2007. *Microvawe Assisted Transesterification of Rapeseed Oil*. Department of Chemical Engineering, Anadolu University, Turkey.

[7] Knothe G. and R. O. Dunn. 2001. *Biofuel Derived From Vegetable Oils and Fats, Oleo-chemical Manufacture and Applications*. Sheffield Academic Press.

[8] Meher L. C., D. V. Sagar, and S. N. Naik. 2006. Technical Aspects of Biodiesel Production by Transesterification A Review. *Renew Sust Energy Rev*. 10: 248–268.

[9] Merkisz, J., M. Kozak, P. Bielaczyc, and A. Szczotka. 2002. An Investigation of Influence of Diesel Fuel Sulphur Content on Particulates Emissions from Direct Injection Common Rail Diesel Vehicle. *Journal of KONES Internal Combustion Engines*. 3(4): 214–223.

[10] Mittelbach, M. and C. Remschmidt. 2004. *Biodiesel: The Comprehensive Handbook.* 1st Ed. Boersedruck Ges.m.b.H. Vienna.