Jurnal Teknologi, 57 (Sains & Kej.), Jan. 2012: 23–32

EFFECTS OF FEEDSTOCK AND CATALYST CONCENTRATION ON BIODIESEL PRODUCTION

NORZITA NGADI[1*], HAJAR ALIAS[2] & SITI AKTAR ISHAK[3]

Abstract. In this study, production of biodiesel from new and used palm and soybean oils was carried out using a transesterification method. The effect of catalyst amount used towards the percentage yield, soap content and heat of combustion of the biodiesel produced was investigated. The soap content and heat combustion of the biodiesel were determined using titration (AOCS Cc-95) and heat calorimeter bomb (ASTM D240-09), respectively. The results showed that catalyst concentration of 0.5 w/w% gave the best result in terms of yield of biodiesel produced from both palm and soybean oils. However, the quality of biodiesel (i.e. soap content and heat of combustion) produced from palm and soybean oils behaved differently towards catalyst concentration. Overall, both oils (palm and soybean), either new or used oil apparently showed no significant difference in term of yield or qualities of biodiesel produced. This indicates that the used oil has high potential as an economical and practical future source of biodiesel.

Keywords: Biodiesel; heat of combustion; transesterification; palm oil; soybean oil

Abstrak. Dalam kajian ini, penghasilan biodiesel daripada minyak kelapa sawit dan kacang soya yang baru dan yang telah digunakan telah dijalankan menggunakan kaedah transesterifikasi. Kesan mangkin yang digunakan terhadap peratusan hasil, kandungan sabun dan haba pembakaran biodiesel telah dikaji. Kandungan sabun dan haba pembakaran biodiesel telah dikenalpasti dengan menggunakan titrasi (AOCS Cc-95) dan haba kalorimeter bom (ASTM D240-09), masing-masing. Keputusan menunjukkan mangkin berkepakatan 0.5% memberikan hasil dan kualiti biodiesel yang terbaik. Secara keseluruhannya, kedua-dua minyak (kelapa sawit dan kacang soya), sama ada yang baru atau yang telah digunakan menunjukkan tiada perbezaaan yang ketara dari segi hasil dan kualiti biodiesel yang dihasilkan. Ini menunjukkan bahawa minyak yang telah di gunakan mempunyai potensi yang tinggi sebagai sumber yang murah dan praktikal untuk penghasilan biodiesel di masa hadapan.

Kata kunci: Biodiesel; haba pembakaran; transesterifikasi; kelapa sawit; kacang soya

[1-3] Faculty of Chemical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru
* Corresponding author: norzita@cheme.utm.my

1.0 INTRODUCTION

Due to the lack of conventional fossil fuels and increasing awareness to environmental protection, the utilization of biofuel from biorenewable resources have attracted worldwide interest. With recent increases in petroleum prices, there is renewed interest in vegetable oil and their derivatives as alternative fuels for diesel engines. Vegetable oils have become more attractive recently because of their environmental benefits and the fact that they come from renewable resources [1]. However, the major problem associated with the use of pure vegetable oils as fuels is caused by high fuel viscosity in compression ignition and resulting injector fouling and other engine problems. The high viscosity of the oil can be reduced by transesterification process [2]. Transesterification is a reaction process between triglycerides with alcohol in the presence of catalyst to produce biodiesel and glycerol. The catalyst can be alkalis [3], acids [4], or enzymes [5].

Numerous studies have been carried out on various aspects of biodiesel production for use in diesel engine. Most of the current challenges concern with the reduction of production cost which is still higher than petrodiesel owing to higher cost of non-edible oil resources. The waste cooking oil (WCO) available from restaurants, food processing industries, fast foods industries has been found to be one of the resources that can be used to produce biodiesel with much less required for its production except collection and refinement. Saiffudin and Chau [6] studied the transesterification of used frying oil with 0.5% NaOH in ethanol using microwave irradiation and found that there is considerable enhancement in the reaction rates. Silva *et al.* [7], had used catalyst of Cu (II) and Co (II) ions adsorbed in chitosan in transesterification of soybean and babassu oils. They found out that conversion of oils in biodiesel was better when used Co (II) adsorbed in chitosan. Freedman *et al.* [8] reported the transesterification of soyabean and other oils with methanol and butanol to examine the effect of alcohol type on the transesterification process. Noureddini and Zhu [9] studied the effect of mixing of soyabean oil with methanol on the kinetics of reaction using one phase transesterification process and found that the mixing had profound effect on the biodiesel yield. Jain *et al.* [10] reported that biodiesel yield of 90.6% was obtained from acid base catalyzed transesterification of waste cooking oil.

One of the most important properties of biodiesel is its heating value. Heating value (HV), or sometimes called the calorific value or heat of combustion is the standard measure of the energy content of a fuel. The heating value is obtained by the complete combustion of a unit quantity of solid fuel in an oxygen-bomb colorimeter under carefully defined conditions. The gross heat of combustion or higher heating value (GHC or HHV) is obtained by oxygen-bomb colorimeter method as the latent heat of moisture in the combustion products is recovered. The higher heating value is one of the most important properties of a fuel. Higher heating values of biomass-derived fuels have been estimated using their proximate and ultimate analysis data [11]. It has also been shown that an estimate of the heating values of vegetable oils can be calculated using saponification and iodine data of the oils. The higher heating value of a fuel increases with increasing carbon number in fuel molecules and also increases as the ratio of carbon and hydrogen to oxygen and nitrogen increases [12].

The objective of this study was to investigate the effect of catalyst content on the yield and quality (i.e. heat of combustion and soap content) of biodiesel fuel produced from used vegetable oils (i.e. palm oil and soybean oil) by transesterification method. The experiment was also conducted using new palm and soybean oils as a comparison.

2.0 MATERIAL AND METHOD

The fresh palm and soybean oils were obtained from commercial sources and used without further purification. The used palm and soybean oils were obtained from several cafes in Universiti Teknologi Malaysia, Johor. The fatty acid composition of oil and its waste cooking oil (WCO) was determined by Gas Chromatography. The samples were converted to biodiesel by transesterification process with the presence of sodium hydroxide with different concentrations (i.e. 0.25, 0.5, 0.75, 1 and 1.5 w/w %) as a catalyst. The temperature was kept constant at 55-60°C. Meanwhile, the ratio between oil and alcohol was kept constant at 1:5. The heat of combustion of the biodiesel was measured in a bomb calorimeter according to ASTM D2015 standard method. An oxygen-bomb was pressurized to 3 MPa with an oxygen container. The bomb was fired automatically after the jacket and bucket temperatures equilibrated to within acceptable accuracy of each other. Meanwhile, the soap content of biodiesel was determined using titration (AOCS Cc 17-95 test).

3.0 RESULTS

3.1 Characteristics of Raw Material

Table 1 tabulates the fatty acid composition of palm and soybean oils (i.e. new and used oils).

Table 1 Fatty acid composition (%) for different source of oil

Component	New palm oil	Used palm oil	New soy bean	Used soy bean
C16:0	44.4	7.3	10.4	4.6
C16:1	0.2	0.24	0.37	2.8
C18:0	4.1	2.01	4.6	1.3
C18:1	39.3	49.6	24.6	48.7
C18:2	10.2	5.83	52.8	34.9
C18:3	0.4	6.0	6.2	10.2
C20:0	0.3	0.11	0.68	0.8
C20:1	ND	0.11	ND	1.5

*ND indicates that composition was not determined

3.2 Effect of Catalyst Amount on Percentage Yield of Biodiesel Produced from Palm Oil

Figure 1 shows the effect of amount of catalyst used on the percentage yield of biodiesel produced from new and used palm oil. Both oils showed the same trend with the respect of catalyst amount; zero yield with the absence of catalyst and then increased rapidly at catalyst concentration of 0.5 w/w% before decreased gradually with the addition of more catalyst. Catalyst at 0.5 w/w% gave the highest yield of biodiesel, about 97 and 64% for new and used palm oil, respectively. Biodiesel yield from new palm oil generally was higher than that from used palm oil. Overall, the production of biodiesel was apparently better when using new palm oil as a feedstock than using used palm oil.

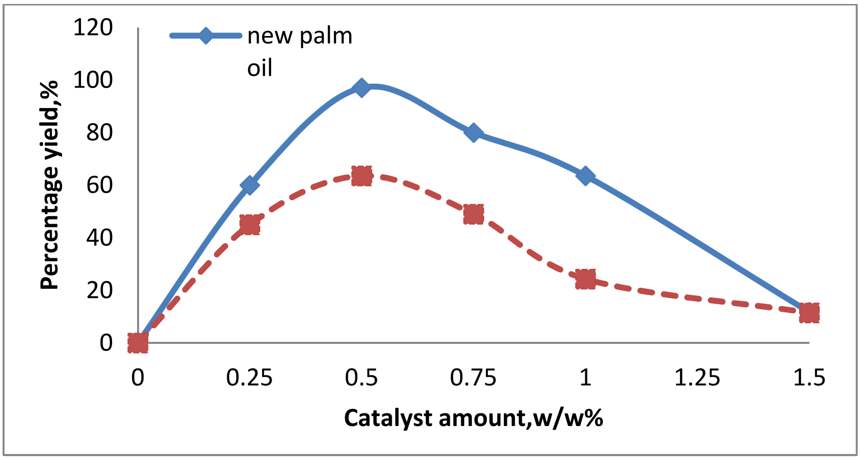

Figure 1 Effect of catalyst amount on the percentage yield of biodiesel produced from new and used palm oils

3.3 Effect of Catalyst Amount on Percentage Yield of Biodiesel Produced from Soybean Oil

Figure 2 presents the effect of amount of catalyst used on the percentage yield of biodiesel produced from new and used soybean oil. As can be seen, the trend was the same as shown by palm oil; the production of biodiesel increased with the increasing of catalyst concentration up to 0.5 w/w% then reduced with addition of more catalyst. The highest yield was achieved at catalyst concentration of 0.5 w/w%. At this point, the yield was almost the same either using new or used oil, at about 97%. As expected, new oil generally produced higher yield of biodiesel compared to used oil.

3.4 Effect of Catalyst Amount on Soap Content of Biodiesel Produced From Palm and Soybean Oils

Figure 3 represents the effect of catalyst amount on the soap content of biodiesel produced from new and used palm oils. As expected, the soap content was higher when using used oil compared to new oil. The soap content increased with the increasing of catalyst concentration.

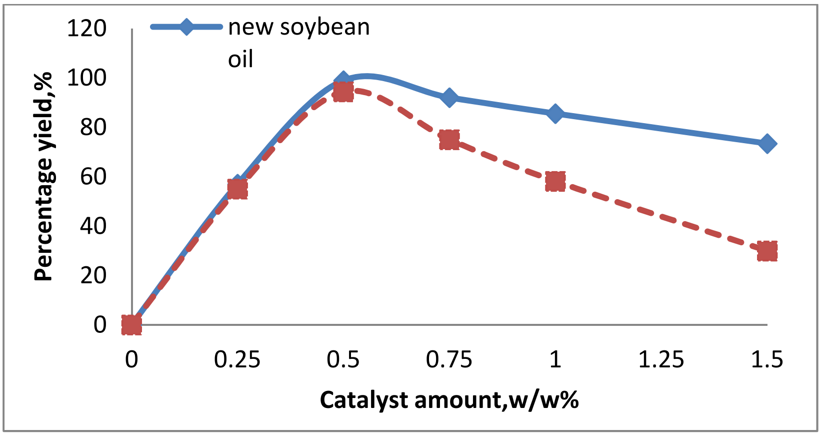

Figure 2 Effect of catalyst amount on the percentage yield of biodiesel produced from new and used soybean oils

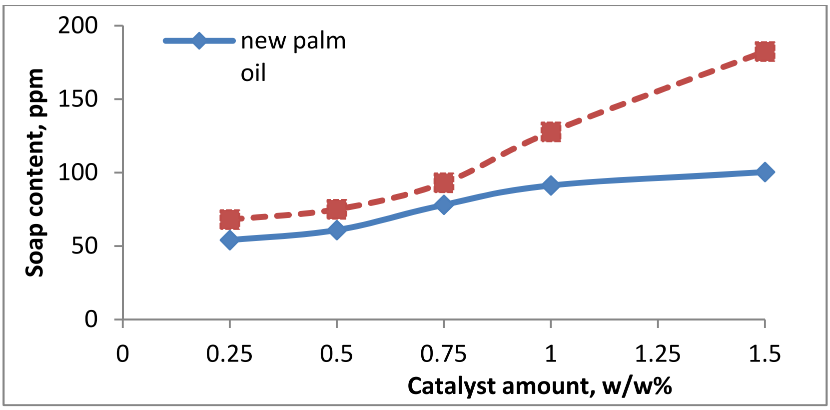

Figure 3 Effect of catalyst amount on the soap content of biodiesel produced from new and used palm oils

Figure 4 represents the effect of catalyst amount on the soap content of biodiesel produced from new and used soybean oils. Like palm oil, used soybean oil produced biodiesel with higher soap content than that of new palm oil. The soap content also increased with the increasing of catalyst amount.

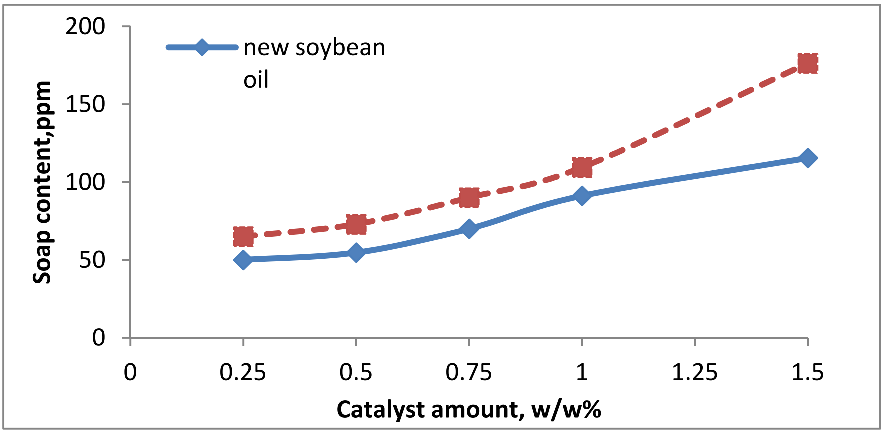

Figure 4 Effect of catalyst amount on the soap content of biodiesel produced from new and used soybean oils

3.5 Effect of Catalyst Amount on Combustion Heat of Biodiesel Produced from Palm and Soybean Oils

Figure 5 represents the effect of catalyst amount on the combustion heat of biodiesel produced from new and used palm oils. As can be seen the catalyst amount seems have no effect on the heat of combustion of biodiesel produced by new oil, at about 40 MJ/kg. In contrast, for used oil, the heat of combustion was reduced from about 39 to 28 MJ/kg as the catalyst concentration increased from 0.25 to 1.5 w/w%.

Figure 6 represents the effect of catalyst amount on the combustion heat of biodiesel produced from new and used soybean oils. Both oils showed an almost similar trend with the respect of catalyst amount; the heat of combustion increased steadily with increasing of catalyst amount before decreased with addition of more than 1 w/w% catalyst. Catalyst ranged from 0.75 to 1 w/w% gave the highest of combustion heat, about 40 and 39.5 MJ/kg for new and used oil, respectively.

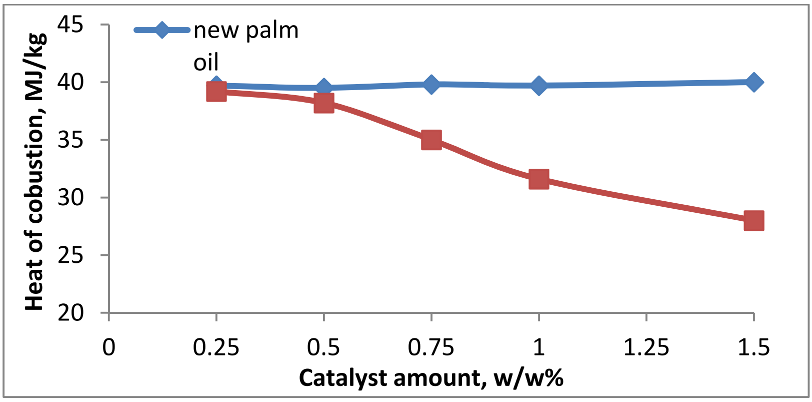

Figure 5 Effect of catalyst amount on the combustion heat of biodiesel produced from new and used palm oils

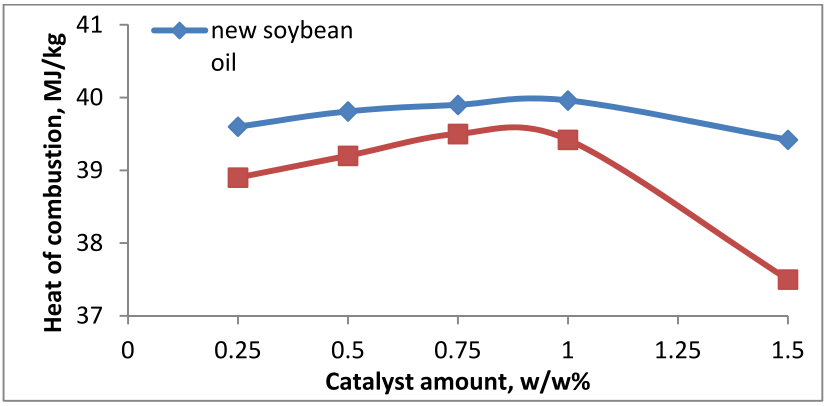

Figure 6 Effect of catalyst amount on the combustion heat of biodiesel produced from new and used soybean oil

4.0 DISCUSSION

Production of biodiesel is affected by many parameters such as type of feedstock, type of catalyst, catalyst concentration, temperature and pH [13,14]. In this part of study, only type of feed stock and catalyst concentration were taken into consideration to determine their effects toward the yield and quality of biodiesel produced. It is clearly shown that, amount of catalyst plays an important role in the production of biodiesel. The production of biodiesel was optimum at certain amount of catalyst. Too much catalyst hindered the reaction of transesterification. It is expected that excessive amount of catalyst leads to the formation of soap and thus lowering the reaction rate. This is the reason why catalyst content showed a linear relationship with the soap content. On the other hand, soap content showed an inverse relationship with the yield of biodiesel; as soap content increased, the yield decreased. The rise in the soap formation causes dissolution of methyl ester in glycerol layer hence reduces the production of biodiesel. Soap formation in biodiesel should be avoided on many counts. The main problem is that it tends to congeal up on the fuel filter fibers which lead to plug fuel filter. Besides, when soap is burned in a diesel engine it leaves behind an ash residue. This residue can manifest itself as higher levels of soot out the tailpipe or even build up on fuel injectors and in the combustion chamber. Nevertheless, the amount of soap content in biodiesel produced in this study was lower than the AOCS standard (i.e. 200 ppm). Thus, the biodiesel produced should not pose any threat to the fuel filter or to the engine.

The heat of combustion is an important property defining the energy content and thereby the efficiency of biodiesel produced. There were different effects of catalyst content on heat of combustion of biodiesel produced from palm oil and soybean oils. A reduction of heat of combustion with the catalyst content for biodiesel produced from used palm oil is believed to associate with the soap content. As the soap content increased, the viscosity of biodiesel is increased. Thus, lowering the heat of combustion since high viscosity leads to the reduction of heat of combustion [2]. However, there is no specific explanation why the heat of combustion for new palm and soybean oil was almost the same with the catalyst used. Under optimum catalyst content, the heat of combustion of biodiesel from both type of feedstock was consistent with other work, which is around 39 to 40 MJ/kg [2].

Overall, both oils (palm and soybean), apparently showed no significant difference in term of yield or qualities of biodiesel produced. This indicates that the used oil has high potential as an economical and practical future source of biodiesel.

5.0 CONCLUSION

From this study, it was clearly shown that catalyst amount played a significant role as compared to type of feedstock in biodiesel production. The study also had shown that the used oil has high potential as an economical and practical future source of biodiesel.

REFERENCES

[1] Bhatia, S., Sang, O.Y., Twaiq, F., Zakaria, R., Mohamed, A. R. 2003. Biofuel Production from Catalytic Cracking of Palm Oil. *Energy Source*. 25: 859–69.

[2] Demirbas, A. 2008. Relationships Derived from Physical Properties of Vegetable Oil and Biodiesel Fuels. *Fuel*. 87: 1743-1748.

[3] Zhang, Y., Dub, M. A., McLean, D. D., Kates, M. 2003. Biodiesel Production from Waste Cooking Oil: Economic Assessment and Sensitivity Analysis. *Bioresource Technology*. 90: 229-40.

[4] Furuta, S., Matsuhashi, H., Arata, K. 2004. Biodiesel Fuel Production with Solid Superacid Catalysis in Fixed Bed Reactor under Atmospheric Pressure. *Catalyst Communication*. 5: 721-723.

[5] Du, W., Xu, Y., Liu, D., Zeng J. 2004. Comparative Study on Lipase-Catalyzed Transformation of Soybean oil for Biodiesel Production with Different Acryl Acceptors. *Journal Molecular Catalyst B*: *Enzyme 30*: 125-129.

[6] Saifuddin, N. and Chua, K. H. 2004. Production of Ethyl Ester (Biodiesel) from Used Frying Oil: Optimization of Transesterification Process Using Microwave Irradiation. *Journal ofChemistry*. 6: 77-82.

[7] Silva, R. B., Neto, A. F. L., Santos, L. S. S., Lima, J. R. O., Chaves, M. H., Santos, J. R. and Moura, E. N. 2008. Catalyst of Cu(II) and Co(II) Ions Adsorbed in Chitosan Used in Transesterification of Soy Bean and Babassu Oils. A New Route for Biodiesel Syntheses. *Bioresource Technology*. 99: 6793-6798.

[8] Freedman, B., Butterfield, R. O., Pryde, E. H. 1986. Transesterification Kinetics of Soybean Oil. *Journal of the American Oil Chemists' Society*. 63: 1375.

[9] Noureddini, H., and Zhu, D. 1997. *Kinetics of Transesterification of Soybean Oil. Journal of the American Oil Chemists Society*. 74: 1457.

[10] Jain, S., Sharma. M. P. and Rajvanshi, S. 2011. Acid Base Catalyzed Transesterification Kinetics of Waste Cooking Oil. *Fuel Processing Technology*. 92: 32-38.

[11] Demirbas, A., Gullu, D., Caglar, A., Akdeniz, F. 1997. Estimation of Calorific Values of Fuels from Lignocellulosic. *Energy Source*. 19: 765–770.

[12] Demirbas, A. 1997. Calculation of Higher Heating Values of Biomass Fuels. *Fuel*. 76: 431–434.

[13] Lu, H., Liu, Y., Zhou, H., Yang, Y. 2009. Production of Biodiesel from Jatropha Curcas L. Oil. *Computers and Chemical Engineering*. 33: 1091-1096.

[14] Haseeb, A.S.M.A., Sia, S. Y., Fazal, M. A., Masjuki, H. H. 2010. Effect of Temperature on Tribological Properties of Palm Biodiesel. *Energy*. 35: 1460-1464.