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Effect of Amount of Catalyst, Agitation Rate, and Methanol to Oil Molar Ratio using Mixed Catalyst Derived from Coconut Waste and Eggshells

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ABSTRACT

This paper studies the effect of calcination mixed waste catalyst for optimization FAME yield. Coconut waste ash and eggshells was used as mixed heterogeneous catalyst. The parameter investigated including, amount of catalyst, agitation rate, and methanol: oil molar ratio. The factorial design was applied at three levels of methanol: oil molar ratio (18:1-24:1), amount of coconut catalyst (1wt%-5wt%) and agitation rate (100rpm-350rpm). The highest biodiesel yield, 82.25% was achieved at 350 rpm, 18:1 methanol to oil ratio, and 5 wt% amount of catalyst. This study proves that mixed catalyst capable to increase the yield of biodiesel.

1. Introduction

The depletion of fossil fuels due to increase of population necessitates the usage of alternative renewable sources in recent years. Renewable or sustainable energy sources include hydropower, biomass or biofuels, geothermal, wave and solar energy. Mostly, the renewable energy resources help to supply energy for electrical power generation and transportation sectors simultaneously, save the environment and reduce the dependence on fossil fuels [1].

Most of the energy demand is fulfilled by conventional energy sources like coal, petroleum, and natural gas. Commonly transport is the almost totally dependent on fossil, especially petroleum [2]. In developed countries, use of modern technologies and efficient bioenergy conversion, becoming cost wise competitive with fossil fuels. The National Biofuel Policy was announced by Malaysian government and it proposal is to produce B5 blend biodiesel which is consist of 5% processed palm

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oil with 95% petroleum diesel for domestic market [3]. Biomass energy includes wastes, standing forests, and energy crops. It also may involve animal waste. Biomass energy able to be supplied almost 90 percent of the energy.

Selecting catalyst from waste source such as shells, ashes, rocks and bones should be encouraging to save our environment [4-6]. The reusable of catalyst can be work up to six times without reduce their efficiencies. Using catalyst from waste materials is an advantage due its abundance; thus, where the waste will be collected and recycled and indirectly saves the environment. Besides, catalyst from waste source material is more affordable and sustainable.

Reducing the cost of production is the most important factor that need to be considered as it contributes about 75% of the overall cost [7]. Furthermore, the use of homogeneous catalysts will increase the production cost as it leads to soap formation, the catalyst cannot be reused, and produces large amount of wastewater [8-11]. In this study, heteregonoues catalyst helps to reduce the cost as it will be produced from waste source and can be reused. Thus, heterogeneous catalyst is considered as green process as it exhibit in less corrosive character, leading to safer, cheaper and more environmentally operation [7, 12]. Therefore, this study is conducted to determine the optimum methanol to oil molar ratio, amount of catalyst and agitation rate to produce the highest yield of biodiesel.

2. Materials and Methods

2.1 Materials

Coconut waste and egg shells were collected from a shop which produces coconut milk at Pasar Besar Gombak, Malaysia. Methanol and n-Hexane was bought from Sigma Aldrich sdn bhd.

2.2 Transesterification

The temperature and time for reaction was setup at steady state temperature which is at 60°C in 3 hours, the parameters which are varied in this experiment are amount of coconut waste catalyst in the range between 1-5wt%; 1% of the eggshell was added into each weight percent coconut waste and the agitation rate was varied at 350 rpm, 225 rpm and 100 rpm. Methanol to oil molar ratio also was varied between 18:1-24:1 as shown in Table 1.

The experimental design was analyzed and done by using Design Expert 7.0.1 and the experimental design selected for this study is Central Composite Design (CCD) where the response measured yield was fatty acid methyl ester (FAME). There are four variable need to be varied such as molar oil to methanol, catalysts concentration, and agitation rate of incubator shaker. The experimental run was 17 with three centre point.

Table 1
Variables and level used in the central composite design

Variables (factors)	Factor coding	Unit	Levels		
			Low (-1)	Center (0)	High (1)
Agitation rate	A	rpm	100.00	225.00	350.00
Methanol to oil ratio	B	-	18:1	21:1	24:1
Amount of catalyst	C	wt%	1.00	3.00	5.00

3. Results and Discussion

Table 2 shows the ANNOVA for response surface reduced quadratic model. The Model F-value of 245.63 implies the model is significant. There is only a 0.01% chance that a "Model F-Value" this large could occur due to noise. With the values of "Prob > F" less than 0.0500 indicate model terms are significant. In this case B, C, B^2, C^2, BC are significant model terms. Values greater than 0.1000 indicate the model terms are not significant. The "Lack of Fit F-value" of 8.03 implies there is a 5.93% chance that a "Lack of Fit F-value" this large could occur due to noise.

Table 2
ANNOVA for Response Surface Reduced Quadratic Model

Sources	*Sum of Square*	*DF*	*Mean Square*	*F Value*	*Prob >F*	
Model	9115.70	9	1012.86	245.63	< 0.0001	Significant
A						
B	104.73	1	104.73	25.40	0.0015	
C	3483.74	1	3483.74	844.84	< 0.0001	
A^2	4.25	1	4.25	1.03	0.3439	
B^2	23.16	1	23.16	5.62	0.0496	
C^2	1336.26	1	1336.26	324.06	< 0.0001	
AB	21.44	1	21.44	5.20	0.0566	
AC	17.69	1	17.69	4.29	0.0771	
BC	49.57	1	49.57	12.02	0.0104	
Residual	28.86	7	4.12			
Lack of Fit	26.40	4	6.60	8.03	0.0593	Non significant
Pure Error	2.47	3	0.82			
Cor Total	9144.57	16				

The "Pred R-Squared" of 0.9674 is in reasonable agreement with the "Adj R-Squared" of 0.9928."Adeq Precision" measures the signal to noise ratio. A ratio greater than 4 is desirable. Your ratio of 36.172 indicates an adequate signal. This model can be used to navigate the design space. The model's goodness to fit was checked by determination coefficient R^2. In this case the value of R^2 is 0.9968 which is closer to 1 denotes better correlation between the observed and predicted responses. The result obtained from the central composite design were fitted to an equation explain the relationship of amount of catalyst used on the FAME yield conversion, Y. The final equation in terms of (coded factors) experimental data

$$Y = 80.01 + 0.41 * A + 3.79 * B + 22.64 * C + 1.27 * A^2 - 2.98 * B^2 - 22.60 * C^2 - 1.98 * A * B + 1.87 * A * C - 3.14 * B * C \quad (1)$$

where A is agitation rate (rpm), B is methanol: oil and C is amount of coconut catalyst.

Figure 1 shows the interaction between agitation rate and methanol: oil on FAME yield at constant amount of catalyst, 3wt%. FAME yield was the highest at 83.7% with increase in ratio of methanol: oil (24:1) and decrease in agitation rate (100 rpm). As state by a researcher that, to achieve a high yield of ethyl ester, alcohol must be used in excess [13]. This is because, in trans esterification of palm oil, triglyceride reacts with an alcohol in presence of base as catalyst, producing mixing of fatty acids alkyl ester and glycerol.

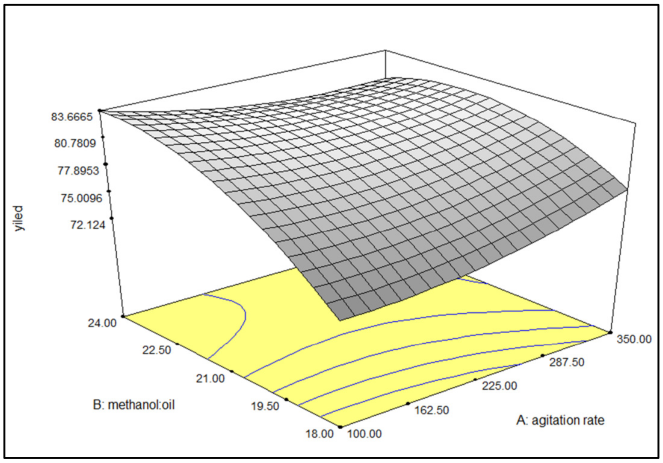

Fig. 1. Effect of agitation rate and methanol: oil

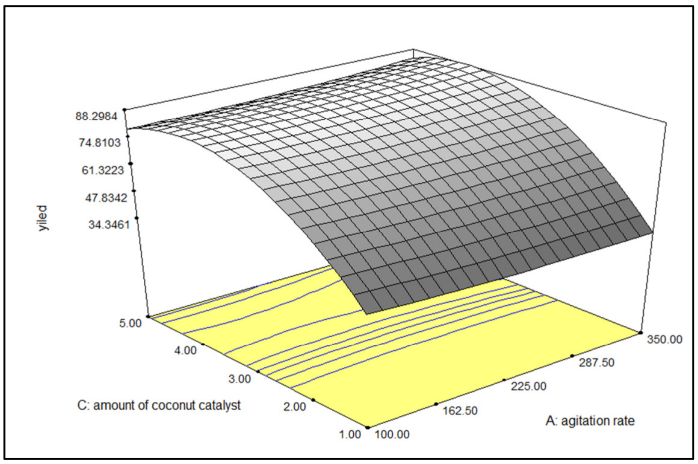

Fig. 2. Effect of agitation rate with amount of coconut waste catalyst

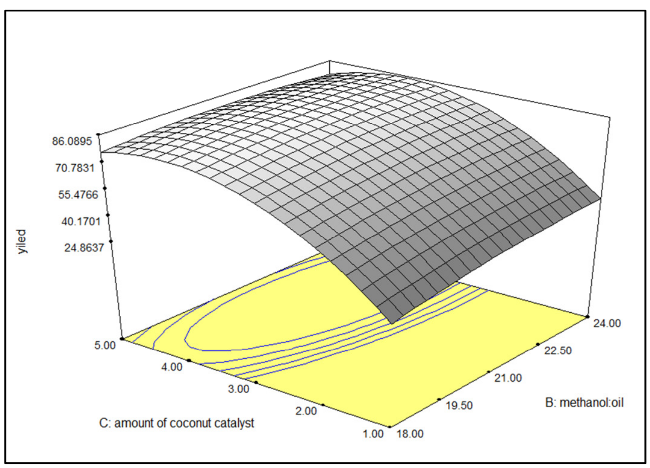

Fig. 3. Effect of methanol: oil with amount of coconut waste catalyst

Figure 2 describes that at range of catalyst amount of 3.5-4wt% at 350 rpm the highest yield achieved at 88.3%. Painstil (2013) reported that by increasing amount of catalyst, yield of ethyl ester becomes high. As the amount of catalyst increase, it also increases the contact surface area and reactant and directly influencing the conversion [14]. Figure 3 shows that at range 4-7wt% with 24:1 of catalyst and molar ratio of methanol: oil respectively, the highest yield of 86% was achieved. Feuge and Gros (1949) and Freedman, et al (1984) studied that, only at initial stage of reaction both parameter; time and temperature has affected the yield of methyl ester but after several hours the result was steady and reaches optimum was at 3 hours [11, 15].

4. Conclusion

The objectives of this study were to investigate the optimum condition for biodiesel production using mixed catalyst of coconut waste and eggshell. From the results, the highest FAME yield produced was 82.25% at agitation rate of 350 rpm, methnol to oil ratio of 18:1 and amount of catalyst of 5 wt%.

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References

[1] S. Şensöz, D. Angın, and S. Yorgun, "Influence of particle size on the pyrolysis of rapeseed (Brassica napus L.): fuel properties of bio-oil," *Biomass and Bioenergy,* vol. 19, pp. 271-279, 2000/10/01/ 2000.
[2] S. Puhan, N. Vedaraman, B. V. Ram, G. Sankarnarayanan, and K. Jeychandran, "Mahua oil (Madhuca Indica seed oil) methyl ester as biodiesel-preparation and emission characterstics," *Biomass and Bioenergy,* vol. 28, pp. 87-93, 2005.
[3] N. H. M. S. Abdul Hamid Jaafar, Basri A Talib, "Economic Impacts of Biodiesel Development Program in Malaysia," *PROSIDING PERKEM V, JILID 2,* pp. 382-391, 2010.
[4] P. Kumar, A. K. Sarma, M. Jha, A. Bansal, and B. Srivastava, "Utilization of Renewable and Waste Materials for Biodiesel Production as Catalyst," *Bulletin of Chemical Reaction Engineering & Catalysis,* vol. 10, pp. 221-229, 2015.
[5] R. Shan, C. Zhao, P. Lv, H. Yuan, and J. Yao, "Catalytic applications of calcium rich waste materials for biodiesel: current state and perspectives," *Energy Conversion and Management,* vol. 127, pp. 273-283, 2016.
[6] G. P. M. Irma Nurfitri, "Potential of Feedstocks and Catalyst from Waste in Biodiesel Preparation," *Energy Conversion and Management,* pp. 395-402, 2013.
[7] F.-l. Pua, Z. Fang, S. Zakaria, F. Guo, and C.-h. Chia, "Direct production of biodiesel from high-acid value Jatropha oil with solid acid catalyst derived from lignin," *Biotechnology for biofuels,* vol. 4, p. 56, 2011.
[8] J. Boro, D. Deka, and A. J. Thakur, "A review on solid oxide derived from waste shells as catalyst for biodiesel production," *Renewable and Sustainable Energy Reviews,* vol. 16, pp. 904-910, 2012.
[9] G. Hayder and P. Puniyarasen, "Identification and Evaluation of Wastes from Biodiesel Production Process " *Journal of Advanced Research in Applied Sciences and Engineering Technology,* vol. 3, pp. 21-29, 2016.
[10] N. Viriya-Empikul, P. Krasae, B. Puttasawat, B. Yoosuk, N. Chollacoop, and K. Faungnawakij, "Waste shells of mollusk and egg as biodiesel production catalysts," *Bioresource technology,* vol. 101, pp. 3765-3767, 2010.
[11] R. Feuge and A. T. Gros, "Modification of vegetable oils. VII. Alkali catalyzed interesterification of peanut oil with ethanol," *Journal of the American Oil Chemists' Society,* vol. 26, pp. 97-102, 1949.
[12] S. L. M. a. R. N. Rubi Romero, "Biodiesel production from heterogenous catalyst," in *ALternative Fuel*, ed Crotia: INTECH, 2011, pp. 1-19.
[13] A. Paintsil, "Optimisation of the Transesterification Stage of Biodiesel Production using statistical methods," 2013.
[14] K.-T. Chen, J.-X. Wang, Y.-M. Dai, P.-H. Wang, C.-Y. Liou, C.-W. Nien*, et al.*, "Rice husk ash as a catalyst precursor for biodiesel production," *Journal of the Taiwan Institute of Chemical Engineers,* vol. 44, pp. 622-629, 2013.
[15] B. Freedman, E. Pryde, and T. Mounts, "Variables affecting the yields of fatty esters from transesterified vegetable oils," *Journal of the American Oil Chemists' Society,* vol. 61, pp. 1638-1643, 1984.