UNIPRA Date: 2020-03-07 17:11 WIB

All sources 100 | Internet sources 25 | Publisher sources 2 | Own documents 3 | Organization archive 2 | Plagiarism Prevention Pool 8

[10] www.researchgate.net/publication/222321306_Heterogeneous_Esterification_of_Oil_With_High_Amount_of_Free_Fatty_Acids
1.1% 53 matches

[11] "s41207-017-0043-8 Jurnal Springer.pdf" dated 2020-03-06
0.9% 61 matches

[12] www.researchgate.net/publication/278653381_Palm_oil_transesterification_in_sub-_and_supercritical_methanol_with_heterogeneous_
0.8% 51 matches

[13] www.researchgate.net/publication/251724733_Transesterification_of_vegetable_oil_into_biodiesel_catalyzed_by_CaO_A_review
0.6% 52 matches

[14] www.researchgate.net/publication/272102327_Transesterification_of_palm_oil_to_biodiesel_by_using_waste_obtuse_horn_shell-deriv
0.3% 51 matches

[15] www.researchgate.net/publication/49634618_Biodiesel_production_using_heterogeneous_catalysts
0.3% 50 matches

[18] www.researchgate.net/publication/287598804_Adsorption_Capacity_of_Coconut_Cocos_nucifera_L_Shell_for_Lead_Copper_Cadmiu
0.3% 31 matches

[19] www.researchgate.net/publication/259638231_Development_of_eggshell_derived_catalyst_for_transesterification_of_used_cooking_o
0.4% 38 matches

[20] eprints.utm.my/id/eprint/cgi/exportview/year/2017/fkk/Atom/2017_fkk.xml
0.4% 40 matches

[21] iopscience.iop.org/article/10.1088/1755-1315/67/1/012021
1.2% 27 matches

[23] www.researchgate.net/publication/299471947_Heterogeneous_calcium-based_bimetallic_oxide_catalyzed_transesterification_of_Elaei
0.6% 32 matches

[24] "Final Revision Full paper Nyoman for BEST 2019 Revised_edit Teplate.doc" dated 2019-08-29
0.2% 41 matches

[27] www.researchgate.net/publication/336137655_Biodiesel_Production_from_Reutealis_Trisperma_Oil_Using_KOH_Impregnated_Eggsh
0.6% 33 matches

[28] www.researchgate.net/publication/339275943_Supermagnetic_Nano-Bifunctional_Catalyst_from_Rice_Husk_Synthesis_Characterizati
0.4% 27 matches

[29] from a PlagScan document dated 2020-02-05 08:54
0.3% 26 matches

[31] www.researchgate.net/publication/326345409_An_overview_of_solid_base_heterogeneous_catalysts_for_biodiesel_production
0.4% 23 matches

[32] www.researchgate.net/publication/299577667_Comparison_of_Biodiesel_Production_between_Homogeneous_and_Heterogeneous_B
0.4% 23 matches

[34] www.onlinelibrary.wiley.com/doi/10.1002/bbb.1914
0.3% 20 matches

[35] Transesterification of jatropha oil using a mixture of natural shells as solid catalyst
0.2% 20 matches

[37] scholars.cityu.edu.hk/files/27565508/Experimental_study_of_the_influence_of_varying_ceiling_height_on_the_heat_release_rate_of_
0.9% 12 matches

[38] www.researchgate.net/publication/317292153_Investigation_of_indirect_benefits_of_PV_rooftop_in_Thailand/fulltext/593eebea458515
0.9% 9 matches

[39] www.researchgate.net/publication/269372433_Transesterification_of_Jatropha_Oil_to_Biodiesel_by_Using_Catalyst_Containing_CaC
0.3% 17 matches

[43] www.chemweb.com/articles/00162361/0104000C
0.3% 16 matches

[45] www.researchgate.net/publication/338534950_Mini-review_of_waste_shell-derived_materials'_applications
0.3% 13 matches

☑ [48] Production of biodiesel by electrolysis method from waste cooking oil using heterogeneous MgO-NaOH nano catalyst
0.3% 13 matches

☑ [49] www.researchgate.net/publication/326230726_Microwave_assisted_synthesis_of_highly_crystalline_nano_CaO_from_waste_egg_shel
0.3% 16 matches

☑ [52] www.researchgate.net/publication/285863029_Biodiesel_-_biodiesel_production_by_transesterification_of_vegetable_oil
0.3% 12 matches

☑ [54] from a PlagScan document dated 2018-05-24 05:08
0.9% 8 matches

☑ [55] from a PlagScan document dated 2018-05-24 02:45
0.9% 5 matches

☑ [58] media.neliti.com/media/publications/169491-EN-effect-of-reaction-time-and-molar-ratio.pdf
0.3% 13 matches

☑ [62] from a PlagScan document dated 2018-05-24 05:42
0.9% 6 matches

☑ [65] from a PlagScan document dated 2018-10-03 06:13
0.9% 4 matches

☑ [66] www.researchgate.net/publication/323729165_Status_of_Suspended_Particulate_Matters_Pollution_at_Traditional_Markets_in_Makas
0.9% 4 matches

☑ [67] "LESTARI-IOP.pdf" dated 2019-09-26
0.9% 4 matches

☑ [68] from a PlagScan document dated 2018-10-03 06:18
0.9% 3 matches
⊞ 5 documents with identical matches

☑ [75] iopscience.iop.org/article/10.1088/1757-899X/152/1/012059/pdf
0.9% 4 matches

☑ [77] "Heri Sujatmiko Jurnal International_2019_J._Phys.:_Conf._Ser._1363_012074.pdf" dated 2019-12-04
0.9% 4 matches

☑ [78] "Curriculum Development.pdf" dated 2019-10-22
0.9% 3 matches
⊞ 4 documents with identical matches

☑ [87] from a PlagScan document dated 2018-04-10 12:10
0.9% 3 matches
⊞ 1 documents with identical matches

☑ [92] from a PlagScan document dated 2020-01-22 16:00
0.3% 4 matches

7 pages, 3839 words

⚠ A very light text-color was detected that might conceal letters used to merge words.

PlagLevel: 2.8% selected / 71.1% overall

167 matches from 111 sources, of which 54 are online sources.

Settings

Data policy: *Compare with web sources, Check against my documents, Check against my documents in the organization repository, Check against organization repository, Check against the Plagiarism Prevention Pool*

Sensitivity: *High*

Bibliography: *Bibliography excluded*

Citation detection: *Reduce PlagLevel*

Whitelist: --

Utilization of eggshell waste as low-cost solid base catalyst for biodiesel production from used cooking oil

N P Asri[1*], B Podjojono[1], R Fujiani[1] and Nuraini[1]

[1]Chemical Engineering Department, Faculty of Engineering,, WR. Supratman University, Surabaya, Indonesia, 601191. *corresponding author: nyoman_puspaasri@yahoo.com

Abstract. A solid CaO-based catalyst of waste eggshell was developed for biodiesel production from used cooking oil. The waste eggshell powder was calcined in air at 900°C for 4 h to convert calcium species in the eggshells into active CaO catalysts. The characterization of CaO catalyst was done by XRD and BET analysis. The CaO catalyst was then introduced for transesterification of used cooking oil (UCO) for testing of its catalytic activity. The experiment was conducted in batch type reactor that consists of three-neck glass equipped by reflux condenser and magnetic stirrer. Before tranesterification process, the UCO was treated by coconut coir powder in order to reduce the free fatty acid content. The result showed that the catalyst was potentially use for transesterification of used cooking oil into biodiesel with relatively high yield of 75.92% was achieved at reaction temperature, reaction time, molar ratio UCO to methanol and catalyst amount of 65° C, 7 h, 1:15 and 6%, respectively.

1. Introduction

The energy consumption has increased every year in line with the increase in human population. This increase occurred in various sectors including transportation, power generation, industry and households. Until now, the world's energy needs are supplied by fossil fuels. By 2030, it is estimated that the increase in energy consumption reaches 53%, so that the oil reserves expected to be exhausted within the next 41-63 years [1]. In addition, the use of fossil fuels continuously, causing environmental impacts such as the increase of CO2 emissions that result in accelerated of global warming, air pollution and other environmental issues. The rapid depletion of fossil fuels and the increasing energy needs has encouraged each country to make savings and conducting various studies to obtain renewable fuels. Biodiesel is a renewable fuel that can be used as a substitute for diesel fuel.

Biodiesel is mono alkyl ester derived from many sources such as vegetable oils, animal fats or used cooking oil. The main factors affecting the cost of biodiesel production is the raw material and the type of catalyst used. In 2012, cooking oil demand in Indonesia is estimated to reach more than 4.7 million tons. After use, the cooking oil will undergo changes in chemical composition and contain carcinogenic compounds. Therefore, the used cooking oil is no longer worthy to be used for food processing. The abundant and availability of used cooking oil can be used as an alternative raw material for the manufacture of biodiesel [2]. Typically, biodiesel was produced through the transesterification process using homogeneous acid / alkaline catalyst [3], [4], [5] that usually called conventional process. This process is fast and efficient, for example more than 95% conversion is achieved at 60° C in 1 h of reaction time. However, it has many disadvantages including the formation of side products such as soaps [6], [7], [8], the complicated separation of the product with the catalyst [3]. In addition, the alkaline waste that formed in large enough quantities also requires a complicated separation process. This separation process requires considerable energy and the increasing of costs

production [7], [9]. Those problems can be mitigated by replacing homogeneous catalysis with solid catalyst. The use of solid acid catalysts in biodiesel production has been studied primarily from transition metal oxides such as zirconia and titanium oxide [9], [10]. The main obstacle of use of acid catalysts requires long reaction times and high reaction temperatures [9], [11]. Solid base catalyst such as calcium oxide [12], magnesium oxide [13], alkali alumina [14], hydrotalcite [15], zeolite [16] seems to be a promising strategy to substitute acid catalyst, but most of them use of synthetic chemicals that are relatively expensive.

This study developed a solid CaO-based catalyst of eggs shell for the production biodiesel from used cooking oil. The purpose of this study is to utilize CaO contained in the eggshell into a solid catalyst instead of homogeneous catalysts that will influence decreasing of biodiesel production costs, so the price of biodiesel can compete with diesel oil. Eggshell has a small porosity and high of $CaCO_3$ content that is indispensable in the industry of biodiesel [17]. Components of the eggshell include calcium carbonate (94%), magnesium carbonate (1%), calcium phosphate (1%), and other organic materials (4%). Based on the pore structure and content of $CaCO_3$, eggshell provides opportunities for development as heterogeneous catalysts [18].

Utilization of this catalyst is expected to provide a solution to obtain a feasibility study of biodiesel production process that is effective and efficient and reduce environmental pollution. The study was conducted in the scale laboratory includes several stages, namely preparation of catalysts, catalyst characterization, and testing catalyst activity to determine the best operating conditions include amount of catalyst and reaction time.

2. Materials and Methods

2.1. Materials

Waste cooking oil was found from local street food vendors in Surabaya, East Java. The physical and chemical characteristics of UCO were analyzed using several methods based on the procedure described elsewhere [2]. The free fatty acid (FFA) content of 4.4946% was analyzed based on American Oil Chemist (AOCS) official Method (Ca 5a-71, 1993). Meanwhile, its density and water content of 0.9219 g/cm^3 and 0.78%, respectively were analyzed based on ISO 662 – 1089. FAME standards and internal standards of chromatographic grade were obtained from Sigma–Aldrich (Switzerland). Technical grade of methanol was purchased from local supplier Bratacho-Chem. Meanwhile eggshell was collected from the local bakeries in Surabaya, East Java, Indonesia.

2.2. Catalyst preparation and characterization

At first, the eggshells being crushed into small chips, then soaked and rinsed thoroughly several times with hot water to remove the impurities and other interference materials. The clean eggshell chips dried at 110℃ for 24 h in the dry oven. The dried chips eggshells then powdered and sieved to the size of qualifying on 100 mesh and retained on 200 mesh. Calcination process was performed in the muffle furnace at 900℃ for 4 h under static air. Surface area analysis of the catalyst was examined using Brunauer-Emmett-Teller (BET) methods. Sample was degassed at 105 ℃ prior to analysis and the adsorption of N_2 was measured at -196 ℃. Meanwhile, X-ray diffraction (XRD) was measured by XPert MPD using Cu Ka radiation. The prepared catalyst from eggshell was assigned as ES-CaO, and then kept in a desiccator in the presence of silica gel in order to avoid water and CO_2 contacting with the catalyst.

2.3. Transesterification process

In this research, the collected UCO was pre-treated based on the procedure described elsewhere [2], [8]. First, the collected UCO was filtered to remove the food residues or the suspended particulate matters, and then it was heated at 100-105ºC for 30 minutes to remove the excess of water content. Further, UCO was treated by adsorption process using coconut coir powdered (CCP) (wt.% to the UCO) to reduce the FFA content of the UCO. It has been stated in the last work [2] that the optimum amount of CCP is 7% (wt.% to the UCO), therefore it was used for treating UCO in this work. The treated UCO was analyzed to determine its final FFA content, and then it was ready subjected for transesterification process using ES-CaO catalyst.

Transesterification process was conducted in batch type reactor consists of three neck glass, equipped with reflux condenser and magnetic hot plate stirrer. The reaction was carried out at 65ºC and molar ratio of UCO to methanol 1:15. Meanwhile, the amount of catalyst and reaction time were varied of 3-7% (wt.% o oil) with 1% of range and 2-7 h with range of 1 h, respectively. The amount of ES-CaO catalyst, methanol, and treated UCO were measured and introduced into the reactor, and allowed to keep a while until the reaction temperature of 65°C was reached. The reaction mixtures were stirred thoroughly at constant speed using magnetic stirrer. After desired duration time was reached, the reactor was cold down and the reaction mixtures were withdrawn at room temperature. The mixtures were filtered to separate the catalyst from the liquid phase. The liquid phase was introduced into a separation funnel where the glycerine was decanted, and then the excess methanol was recovered using a rotary evaporator. Biodiesel concentration was analysed by a gas chromatograph GC-14B (Shimadzu) equipped with a flame ionization detector and a capillary column HP-Innowax (30 m × id 0.25 mm, 0.25 μ m). Helium was used as the carrier gas throughout the whole experiment. Biodiesel analyses can be used to calculate the yield of biodiesel (%) defined as Equation 1 [19]

( ) —— (1)

Where, w of ab means weight of actual biodiesel was calculated from weight of biodiesel produced (mg) in the experiment multiple by weight % of FAME in the sample. Meanwhile, W of oil is weight of oil (mg) used in the experiment.

3. Result and Discussion

3.1. Characterization of ES-catalyst

The specific surface area prepared ES-CaO catalyst of 125.927 $m^2 g^{-1}$ was obtained using BET methods. This result is much higher than that crab shells catalyst of 13 $m^2 g^{-1}$ that was stated by Boey et al. (2009) [20]. Meanwhile, mud clam shell and commercial CaO have the surface area of 68.57 and 62.91 $m^2 g^{-1}$, respectively [21].

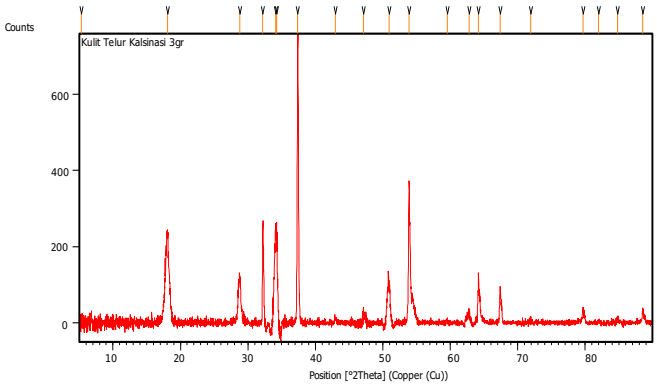

Figure 1. XRD patterns of eggshell (ES-CaO) catalyst calcined at 900°C

X-ray diffraction (X-RD) patterns of ES-CaO was depicted by figure 1. XRD results revealed that the composition of uncalcined eggshell mainly consisted of calcium–magnesium carbonate ($CaCO_3$–$MgCO_3$) with the absence of CaO peak (the figure was not shown). This result confirm with the composition of eggshell that mostly consisted by $CaCO_3$ (94%). However, for the calcined catalyst at 900°C (figure 1), $CaCO_3$ completely converted into CaO and release the CO_2 gas. The narrow and high intense peaks of the calcined catalyst showed the well crystalline structure of the catalyst that mainly consisted of the active ingredient CaO.

3.2. Effect of reaction variable on yield of biodiesel

The yield of biodiesel was affected by many factors, such as the type triglyceride, type of catalyst used, reaction temperature, molar ratio of oil to methanol, catalyst amount or reaction time. Therefore, the

effect of reaction variables was studied in the presence of ES-CaO solid base catalyst. In this work we focused on the influence of the catalyst amount used and the reaction time on yield of biodiesel.
There are 2 keys parameter including free fatty acid and moisture content that are determining the viability of vegetable oils to be used in transesterification process [2], [22]. Water content will accelerate the hydrolysis reaction and simultaneously reduce the amount of ester formation [23]. To achieve 90% yield of biodiesel, then water content of triglyceride that used in the transesterification process not more than 0.5% [24]. Moreover, it was known that higher free fatty acid contents will lead to formation of soap and water. If free fatty acid content more than 3%, the homogeneous base catalyst is not suitable for the transesterification reaction [2], [24].
The UCO that was used in this work contained 4.4946% (wt. %) free fatty acid (FFA). In order to reduce the FFA content of the UCO, it was treated by adsorption process using 7% of coconut coir powder [2]. Coconut coir is one of the agricultural waste products often used as adsorbent in wastewater treatment [25]. Due to its availability and its abundant in the environment, make it to be a good source used in the adsorption process [2], [25]. The nature of coconut coir dust such as good structural stability, high water absorptivity and high porosity enhance its effectiveness as adsorptive or ion exchange capacities. Its composition includes lignin, cellulose, pentosan and ash were 36.15, 33.61, 29.27 and ash 0.61% (wt. % of dry basis), respectively [26]. After adsorption process, the FFA content of UCO was determined using AOCS method. The result showed its FFA content decrease into 0.2079%. Furthermore, the treated used cooking oil is ready for the transesterification process.

3.2.1. Effect of catalyst amount on yield of biodiesel
Investigating the influence of catalyst amount on yield of biodiesel the experiments were performed in varied catalyst amount of 3-7% with range of 1% (wt.% to UCO) under constant stirring speed using reaction temperature, reaction time and molar ratio of UCO to oil at 65 ºC, 1 hr and 1:15, respectively. Figure 2 shows the influence of catalyst amount on yield of biodiesel. As depicted by figure 1, the amount of catalyst was significantly influence on yield of biodiesel. Yield of biodiesel increases with increasing the amount of catalyst. Without the presence of catalyst, no biodiesel was formed (data yield of biodiesel using 0 % catalyst amount was not shown in the figure).

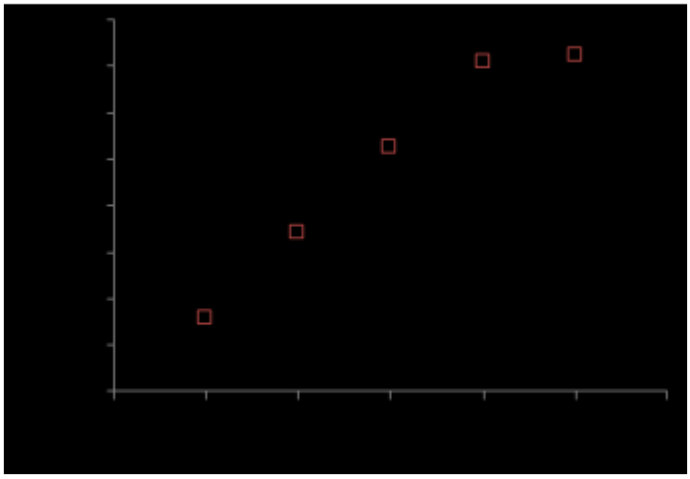

Figure 2. Effect of amount of ES-CaO catalyst on yield of biodiesel

In contrary, yields of biodiesel linearly increase with the increasing the amount of catalyst at 3 up to 6%. It is strongly evidence that the presence of catalyst affected the reaction rate [2]. In this work, the maximum yield of biodiesel of 5.62% was found at 7% catalyst amount of ES-CaO. However, at catalyst loading amount of 6-7% there is no increased significantly on yield of biodiesel. Therefore, for the economic point of view, 6% amount of catalyst was decided as the optimum condition, and it was selected for further studies.

3.2.2. Effect of reaction temperature on yield of biodiesel

Evaluating the influence of reaction time on yield of biodiesel on transesterification of UCO using ES-CaO catalyst, the experiments were conducted by varying time of reaction from 1 to 7 h with range of 1 h. Meanwhile, the others conditions were kept constant, at 65℃, molar ratio treated UCO to methanol of 1:15, and amount of catalyst of 6% (wt. % to UCO).

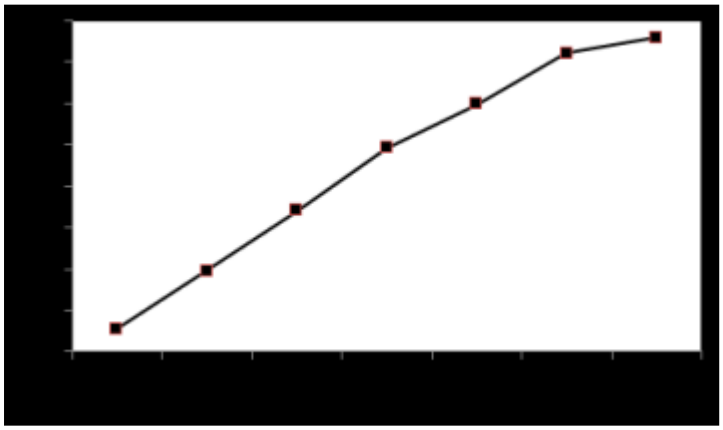

Figure 3. Effect of reaction time (h) on yield of biodiesel (%)

Figure 3 depicted that yield of biodiesel significantly increased with increasing of the time of reaction. In 1 h of reaction, yield of biodiesel was low, because it is a heterogeneous reaction and the fact that mass transfer is slow in the earlier of reaction. Huaping et al. (2006) reported the similar result [27]. After one up to 6 h, yield of biodiesel linearly increase from 5.54 up to 72.05%. At reaction time of 6 up to 7 h, biodiesel yields were gradually increased from 72.05 to 75.92 %. It seems that the equilibrium condition was achieved at 7 h with highest yield of 75.92%. It proved that the yield of biodiesel increased up to certain of reaction time. Refaat et al. (2008) and Asri et al. (2013) stated the similar statement [19], [28]. Therefore, the reaction time of 7 h was decided as the optimum reaction time on transesterification of used cooking oil into biodiesel using ES-CaO catalyst.

4. Conclusion

Calcium oxide (CaO) solid base Catalyst has been successfully prepared from eggshell waste by calcination process at high temperature (900°C). The eggshell waste (ES-CaO) catalyst has been introduced to transesterification process of used cooking oil with refluxed methanol. The high content of free fatty acid in used cooking oil reduced using 7% (wt.% to UCO) of coconut coir powder. The transesterification reaction was carried out under constant stirring speed at 65 ℃ and molar ratio of UCO to methanol 1:15. The result shown, that the amounts of catalyst and reaction time have significant effect on yield of biodiesel. The high enough biodiesel yield of 75.92% was obtained using 6% of catalyst amount within 7 h of reaction time. It proved that the eggshell waste catalyst seems to be very promising for producing biodiesel from used cooking oil. However, the activity of the eggshell catalyst should be improved to achieve the higher biodiesel yield (95%) in a shorter time of reaction. Therefore, the study of developing and engineering of CaO solid base catalyst derived from shell waste is still need to be encouraged to enhance the efficiency of biodiesel production from used cooking oil.

5. References

[1] Kiakalaieh A T, Amin N A S, and Mazaheri H 2013 A review on novel processes of biodiesel production from waste cooking oil Applied Energy 104 683–710

[2] Asri N P, Puspitasari D A, Poedjojono B, and Suprapto 2015a Pre-treatment of waste frying oils for biodiesel production Modern Applied Science 9 7 99-106

[3] Freedman, B, Butterfield RO, and Pryde EH 1986 Transesterification kinetics of soybean oil J American Oil Chemists Society 63 1375-80
[4] Canakci M 2007 The potential of restaurant waste lipids as biodiesel feedstocks Bioresource Technology 98 1 183–190.
[5] Asri N P, Machmudah S, Wahyudiono W, Suprapto S, Budikarjono K, Roesyadi A, and Goto M 2013a Non catalytic transesterification of vegetables oil to biodiesel in sub-and supercritical methanol: a kinetic's study Bulletin of Chemical Reaction Engineering & Catalysis 7 3 215-223
[6] Ilgen O, Akin A N 2008 Development of alumina supported alkaline catalyst used for biodiesel production Jourrnal of Turkey 33 281–287
[7] Zabeti M, Daud W H A M, and Aroua M K 2009 Activity of solid catalysts for biodiesel production: A review Fuel Processing Technology 90 770-777
[8] Asri N P, Poejojono B, Puspitasari D A, Suprapto S, and Roesyadi A 2015b Biodiesel production using double promoted catalyst CaO/KI/ γ-Al_2O_3 in batch reactor with refluxed methanol Springer Procedding in Energy, Energy System And Management Germany Springer Verlag, ch 15
[9] Furuta S, Matsuhashi H and Rata K 2006 Green diesel fuel production with solid amorphous-zirconia catalyst in fixed bed reactor Biomass And Bioenerg 30 870-873
[10] Jitputti J, Kitiyanan B, Rangsunvigit P, Bunyakia K, Attnatho L and Jenvanipanjakul P 2006 Transesterification of kernel oil and crude coconut oil by different solid catalysts Chemical Engineering Journal 116 61-66
[11] Marchetti J M, Miguel V U and Errasu A F 2007 Heterogeneous esterification of oil with high amount of free fatty acids Fuel 86 906–910
[12] Granados M L, Poves M D Z, Alonso D M , Mariscal R, Galisteo F C, Moreno-Tost R, Santamaría J and Fierro J L G 2007 Biodiesel from sunflower oil by using activated calcium oxide Applied Catalysis B: Environmental 73 317–26
[13] Wang Y, Zhu S, He H and Liu X 2007 Transesterification of soybean oil to biodiesel using SrO as a solid base catalyst Catalayst Communication 8 1107-11
[14] Xie W and Li H 2006 Alumina supported potassium iodide as a heterogeneous catalyst for biodiesel production from soybean oil J Molecular Catalysis A: Chemical 255 1-9
[15] Kim M J, Park S M, Chang D R and Seo G 2010 Transesterification of triacetin, tributryin, and soy bean oil with methanol over hydrotalcite with different water content Fuel Process Technology 91 618-24
[16] Noiroj K, Intarapong P, Luengnaruemitchai A and Jai-In S 2009 A comparative study of KOH/Al_2O_3 and KOH/NaY catalyst for biodiesel production via transesterification from palm oil Renewable Energy 34 1145–50
[17] Empikul, V N, Krasae P, Puttasawat B, Yoosuk B, Chollacoop N and Faungnawakij K 2010 Waste shell of mollusk and egg as biodiesel production catalyst Bioresource Technology 101 3765-67
[18] Stadelman, W J 2000 Eggs and egg products. In: Francis, F.J. (Ed.) Encyclopedia of Food Science and Technology 2nd Ed. New York John Wiley and Sons 593–599
[19] Asri N P, Machmudah S, Wahyudiono W, Suprapto S, Budikarjono K, Roesyadi A and Goto M. 2013b Palm oil transesterification in sub and supercritical methanol with heterogeneous base catalyst Chemical Engineering and Processing: Process Intensification 72 63-67
[20] Boey P L, Maniam G P, and Hamid S A 2009 Biodiesel production via transesterification of palm olein using waste mud crab (Scylla serrata) shell as a heterogeneous catalyst Bioresource Technology 100 6362–68
[21] Ismail S, Ahmed A S, Anr R, and Hamdan S 2016 Biodiesel production from castor oil by using calcium oxide derived from mud clam shell Journal of Renewable Energy Article ID 5274917, 8 pages

[22] Gashaw A and Teshita A 2014 Production of biodiesel from waste cooking oil and factors affecting its formation: A review International Journal of Renewable and Sustainable Energy 3 5 92-98
[23] Leung D Y C and Guo Y 2006. Transesterification of neat and used frying oil: Optimization for biodiesel production. Fuel Processing Technology 87 10 883–90
[24] Gnanaprakasam A, Sivakumar V M, Surendhar A, Thirumarimurugan M, and Kannadasan T 2013 Recent strategy of biodiesel production from waste cooking oil and process influencing parameters: A review. Hindawi Publishing Corporation Journal of Energy, 10 pages
[25] Okafor P C, Okon P U, Daniel E F, Ebenso E E 2012. Adsorption capacity of coconut (Cocos nucifera L.) shell for lead, copper, cadmium and arsenic from aqueous solutions International Journal Electrochemical Science 7 12354 –12369
[26] Etim U J, Umoren S A and Ednok U M 2012 Coconut coir dust as a low adsorbent for the removal of cationic dye from aqueous solution Journal of Saudi Chemical Society
[27] Huaping Z, ZongbinW, Duan Shjie CY, Yuangxiong C, Ping Z, Xiaohua L and Zongqiang M. 2006 Preparation of biodiesel catalyzed by solid super base of calcium oxide and its refining process Chinese Journal Of Catalyses 27 5 391-96
[28] Refaat A A, Attia N K, Sibak H A, El Sheltawy S T and El Diwani I 2008 Production optimization and quality assessment of biodiesel from waste vegetable oil International Journal of Environmental Science and Technology 5 1 75-82

6. Acknowledgments
The authors would like gratitude to Directorate of Research and Community Services, Directorate General of higher education, the Ministry of Research Technology and Higher Education of Republic Indonesia, for the financial support through the research grant in the fiscal year of 2017.