

The Development of Biodiesel Production Process from Rubber Seed Oil by Non Catalytic Method and Degumming

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Abstract— A study of the production process of biodiesel from rubber seed oil using non-catalytic method that involving superheated methanol at atmospheric pressure bubble column reactor (BCR) has been reported. The quality of biodiesel generated from the process had not met the standard set by Indonesian Biodiesel Forum (FBI) in 2005. It was allegedly occurring since there was no degumming in the production process so that the sulfur and gum/phospholipid/latex contained by the crude rubber seed oils (CRSO) as results of the pressing process were can not be reduced although the transesterification process was held at a high temperature. The study aimed at producing FBI-2005 standardised biodiesel by involving degumming before the transesterification. There were 4 degumming materials used: (1) NaCl; (2) citric acid or $C_6H_8O_7$; (3) sulfuric acid and NaOH; (4) zeolite and active carbon. The degumming sedimentation were done in two ways; natural and centrifuge (at 1165 rpm for 5 minutes) ways. The best degumming result was processed to be biodiesel under non-catalyst method using BCR superheated methanol under atmospheric pressure with the molar ratio (RM) of 160, at reaction temperature of 290 °C. The biodiesel generated at such process was examined and found that it had met the standard of FBI 2005. The results showed that the degumming using citric acid 0.5% w/w and centrifuge sedimentation was the best method which could reduce gum/phospholipid from 17.1 mg/L to 5.8 mg/L (66% down). The quality of rubber seed biodiesel under degumming process using citrid acid has meet the standard of FBI 2005 than be ready to be marketed.

Keywords-- Rubber seed biodiesel; degumming; Non-catalytic

I. INTRODUCTION

The development of biodiesel process production from catalyst method to non-catalytic method with high temperature and low pressure has been reported. The reactor used is bubble column reactor (BCR) and superheated methanol. The reaction occurs under atmospheric pressure at 290 °C. The CRSO which has a high free fatty acid or FFA (more than 2.5%) can be directly processed through transesterification (without degumming and esterification) without any lathering. The density, cetane number, pour point, flash point, and acid number of non-catalytic method are better than of the catalytic method. While the short comings are the residual carbon contained by rubber seed biodiesel (B100) is quiet high exceeding the standard which at 2.87% in the distillation residue (standard of FBI 2005: max. 0.3%), and sulfur (S) is at 0.72% (standard of FBI 2005: max. 0.05%) so that it is not ready to be marketed at Oil Stations. The high level of residual carbon and sulfur is allegedly caused by a preliminary process without degumming so that the gum/phospholipid contained can not be eliminated although the transesterification is conducted at a high temperature.

An optimum methyl-ester can be obtained at the molar ratio (RM) of 160 and the reaction temperature of 290 °C^[1]. The arising problems are whether the quality of rubber seed biodiesel will meet the standard of FBI 2005 when the additional preliminary process degumming using non-catalytic method with superheated methanol under atmospheric pressure is conducted; what is the better material for degumming; and is there any engine performance improvement generated?

Degumming process is a process of gum/phospholipid separation consisting of phospholipid, protein, residue, carbohydrate, water and resin insoluble in CRSO. Usually, this process is conducted by dehydrating gum/phospholipid or other sewage in order to be more easily separated from the oil, then followed by centrifugation.^[2] The phosphatide components form slime/latex (gum/phospholipid) in CRSO and it is undesirable due to the hidration of triglyceride which causes emulsion during the process and complicates the absorption. The phosphatides which are soluble in CRSO can be separated by draining hot water into CRSO, while the phosphatides which are insoluble can be separated by adding phosphoric acid (H_3PO_4). The degumming process using inorganic acid is commonly performed since it can cause clots so as to facilitate the deposition of dirt. There are some methods can be conducted to separate gum/phospholipid from CRSO: (1) adding phosphoric acid, (H_3PO_4), sulfuric acid (H_2SO_4), hydrochloric acid (HCl), sodium hydroxide (NaOH), citric acid ($C_6H_8O_7$), hidration method, specific reagents such as NaCl, Na_3PO_4 , zeolite and active carbon, (2) using membrane, etc. The addition of NaCl solution in the degumming process is aimed at preventing the phosphatides (lechitin) and compounds containing gum/phospholipid to be insoluble either in oils and water.

Phosphatide has polar part (hydrophylic) and non-polar part (hydrophobic). Hydrophobic groups that are non-polar will be tied to oil, where polar hydrophylic groups will be bound to the NaCl solution. Phosphatide compound (lecithin) containing fatty acid at both positions, glycerol with one phosphate on the third position. Lecithin has its typical nature since each of its molecules has two long hydrophobic tails and the other hydrophylic has a polar character. Thus, lecithin has neutral surfactant characteristics. The polar part of lecithin molecules can be positively charged, negative, or neutral. This dual nature makes the lecithin can be absorbed in the water and oils, forms single layers where the hydrophylic groups are in the water layer and the fatty acids are submerged in the oil layer.^[3] Citric acid ($C_6H_8O_7$) is a weak organic acid which functions to be a chelating agent for binding metal ions which stimulates oxidations in order to be able to prevent the oxidation in the oil after the heating process. It can also be used as a preservative and a pH regulator.^[4] The acidity of citric acid is formed from COOH three carboxyls which release their protons to the solution. This generates citrate ion when occurs. Citrate is very good to be used in a buffer solution to manage the pH of the solution. The citrate ion can react with metal ions and generates citrate salts. Moreover, citrate is also used to bind metal ions with chelating so it is used as a preservative and water hardness remover. At room temperature, citric acid is a white crystalline powder. The sodium hydroxide (NaOH) is a kind of caustic alkali metals that are known as caustic soda or sodium hydroxide. Sodium hydroxide is forming a strong alkaline solution when dissolved in water. NaOH has properties of lathering oil or emulsifying. Degumming using NaOH can absorb slimes and some pigments. The weakness of this process is the formation of soap emulsion which eliminates oils so much.^[5] Therefore, a mixture of H_2SO_4 is used.

Degumming is a process to separate gum/phospholipid contained by oil. Other sewage are difficult to separate if they are in anhydrous condition so they can be deposited by a hydration process. The hydration process can be performed by using steam or adding water or adding weak acid solution. The material used for pre-degumming is H_3PO_4 . In addition to that, sodium hydroxide (NaOH) is also used in the pre-degumming process. Such compound is expected to activate zeolite and active carbon granules to absorb gum/phospholipid and other sewage maximally. Zeolite usually contains silica, aluminium, and oxygen in the frames and cations, water, as well as other molecules existing in the zeolite pores.^[6]

Zeolite is a porous tetrahydrate silicic aluminic mineral which has a three-dimensional frame structure composed of tetrahedral, $[SiO_4]^{4-}$ and $[AlO_4]^{5-}$ interconnected by oxygen atoms to form an open three-dimensional framework, contains channels, cavities and metal ions.^[7] Zeolite is mostly used as absorbent, ion exchangers and catalyst. To improve the properties of natural zeolites that can be used as catalysts, absorbents, or other application, activation and modification are usually done first. The activation of natural zeolite can be done physically and chemically. The physical one is done through the physics particle size reduction, sieving, and heating at high temperature. The goals are to remove organic impurities, enlarge pores and expand the reaction surface. While the chemical one is done through acidification. The goals are to remove inorganic impurities. Further modification of natural zeolite is done to get a new form of cations and frame composition. The modification is usually done by ion exchange, dealumination and isomorphic substitution.^[8]

The other materials which can be used in the process of degumming is active carbon, charcoal activated by CO_2 , moisture, or other chemicals so that the pores will open and thus the absorption rate becomes higher to dyes and odour. Active carbon contains 5–15% water, 2–3% ash and the remaining is carbon. Active carbon is in the amorphous form, composed of flat plates, compiled by C atoms bonded covalently in a hexagonal lattice with one C atom in each corner. These plates are on top of each other forming crystal with hydrocarbons and organic compounds remaining inside.^[9] The adsorption capacity of active carbon depends on its characteristics such as: texture (surface area, pore size distribution), surface chemistry (functional groups on the surface) and ashes. In addition to that, it also depends on the adsorption characteristics are: molecule mass, polarity, molecule size and function groups. The conditions of solution like pH, concentration, and the possibility of adsorption of the other substances also have effects.^[10]

II. EXPERIMENTAL

Physical properties of CRSO are viscosity 5.19 cSt, density 0.9209 g/ml, water content 0.2%, *free fatty acid* (FFA) 6.66%, boiling point 305 °C and gum/phospholipid 17.1 mg/L^[11]. Degumming is performed using various materials are: (1) NaCl; (2) citric acid or $C_6H_8O_7$; (3) sulfuric acid and NaOH; (4) zeolite and active carbon. The goal is to find the best degumming method to eliminate gum/phospholipid and sulfur (S). CRSO which contains the lowest gum/phospholipid and the lowest S will be processed to be biodiesel. Engine performance test and exhaust gas emission test will also be conducted to ensure that the fuel is ready to use by the society.

Method 1: Degumming using NaCl

The ratio of NaCl powder, water and CRSO is shown on Table 1. Preparing the sample 1: First, 3.6 g of NaCl powder is mixed by 80 ml of water then be stirred until dissolved. Samples 2, 3, and so on are prepared by the same manner and the same ratio.

Table 1 The ratio of NaCl powder, water and CRSO

| Sample Number | NaCl powder | | Water % v/v (ml) | CRSO | |
|---------------|-------------|------|---------------------|------|-----|
| | % w/w | (g) | | (ml) | (g) |
| 1. | 1.0 | 3.6 | 20 (80) | 400 | 360 |
| 2. | 1.5 | 5.4 | | | |
| 3. | 2.0 | 7.2 | | | |
| 4. | 2.5 | 9.0 | | | |
| 5. | 3.0 | 10.8 | | | |

CRSO at the amount of 400 mL is heated up to $T = 80^{\circ}\text{C}$, then pour the solution of NaCl (sample 1) into it, stir using *magnetic stirring* for $t = 30$ minutes, then let it get cool at the room temperature. The deposited of gum/phospholipid is done in two ways are natural way and centrifugation at 1165 rpm for 5 minutes. The sediment then is separated by burette. The RSO resulted by degumming process then be tested using sample 1 to determine its gum/phospholipid. Degumming processes using samples 2, 3, 4 and 5 are done in the same way. The Flowchart of degumming process using NaCl is shown in figure 1.

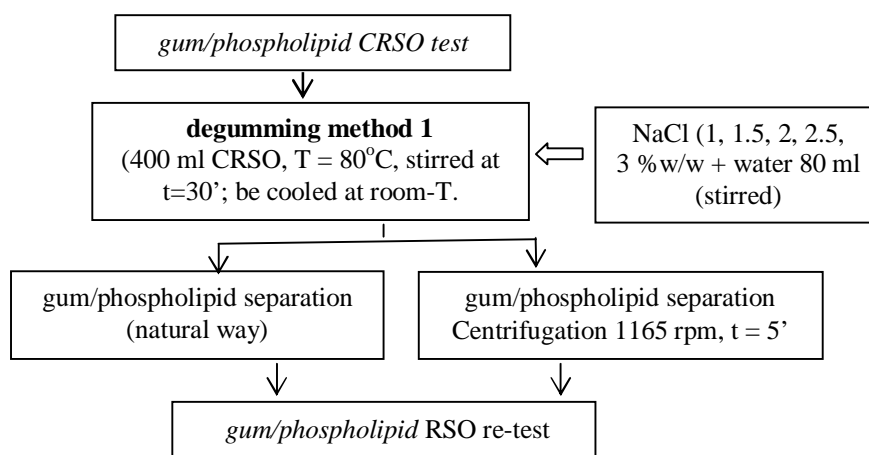


Figure 1 Flowchart of degumming process using NaCl.

Method 2: Degumming using citric acid ($\text{C}_6\text{H}_8\text{O}_7$)

Degumming process in this study is using citric acid powder ($\text{C}_6\text{H}_8\text{O}_7$), while the ratio of citric acid, water and CRSO is shown in Table 2. Preparing the sample 1: citric acid powder ($\text{C}_6\text{H}_8\text{O}_7$) in the amount of 0.36 g mixed with 80 ml of water and be stirred until dissolved. Sample 2,3, and so on also be prepared by the same way and the same ratio. CRSO at the amount of 400 ml is heated up to $T = 80^{\circ}\text{C}$, then pour the solution of citric acid (sample 1) into it and stir it using *magnetic stirring* for $t = 45$ minutes, then let it be cool in the room temperature. While the deposited of gum/fosfolipid is done in two ways are natural way and centrifugation at 1165 rpm for 5 minutes. The sediment then separated by buret. The gum/phospholipid of RSO as the result of degumming using sample 1 then be re-tested. Degumming using samples 2, 3, 4 and 5 are done with the same way. The flowchart of degummig process using citric acid ($\text{C}_6\text{H}_8\text{O}_7$) is shown in Figure 2.

Table 2 Ratio of citric acid ($\text{C}_6\text{H}_8\text{O}_7$), water and CRSO

| Sample Number | Citric acid powder ($\text{C}_6\text{H}_8\text{O}_7$) | | water (ml) | CRSO | |
|---------------|---|------|---------------|------|-----|
| | % w/w | (g) | | (ml) | (g) |
| 1. | 0.1 | 0.36 | 80 | 400 | 360 |
| 2. | 0.2 | 0.72 | | | |
| 3. | 0.3 | 1.08 | | | |
| 4. | 0.4 | 1.44 | | | |
| 5. | 0.5 | 1.80 | | | |

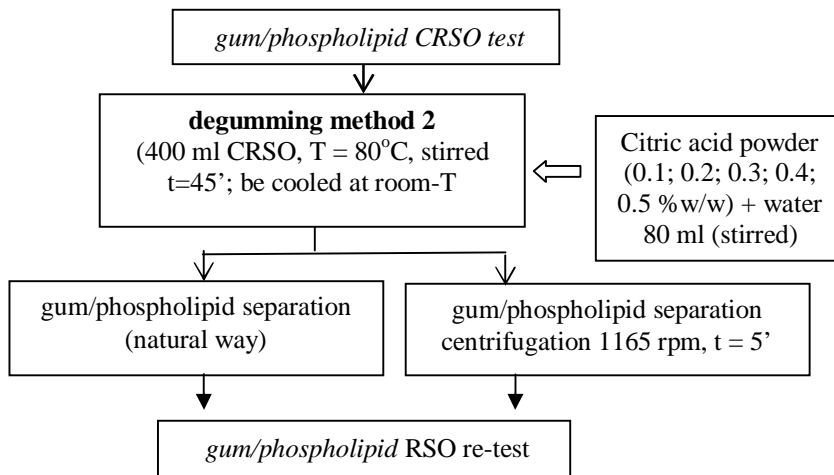


Figure 2 The flowchart of degumming process using citric acid ($C_6H_8O_7$)

Method 3: Degumming using sulfuric acid (H_2SO_4) and NaOH.

The process of degumming in this study is using sulfuric acid (H_2SO_4) and NaOH, with the ratio of sulfuric acid, NaOH and CRSO is shown on Table 3. CRSO in the amount of 400 ml is mixed first by 2 g of sulfuric acid (to reduce the need for NaOH), and boiled up to $T = 100^\circ C$ for $t = 3$ hours, then mixed by NaOH according to the ratio (2, 3, 4, 5 or 6 g). Stir them using *magnetic stirring* for 1 hour and let it be cooled naturally at room-T. The deposited of gum/phospholipid is done using two ways are naturally and centrifugation at 1165 rpm for 5 minutes. The sediment then be separated by burette. The gum/phospholipid of RSO as the result of degumming using sample 1 then be re-tested. Degumming using samples 2, 3, 4 and 5 are done with the same way. The flowchart of degumming process using sulfuric acid (H_2SO_4) and NaOH is shown in figure 3.

Table 3 Ratio of NaOH, sulfuric acid and CRSO

| Sample Number | NaOH | Sulfuric acid (H_2SO_4) | CRSO | |
|---------------|------|-----------------------------|------|-----|
| | (g) | (g) | (ml) | (g) |
| 1. | 2 | 2 | 400 | 360 |
| 2. | 3 | | | |
| 3. | 4 | | | |
| 4. | 5 | | | |
| 5. | 6 | | | |

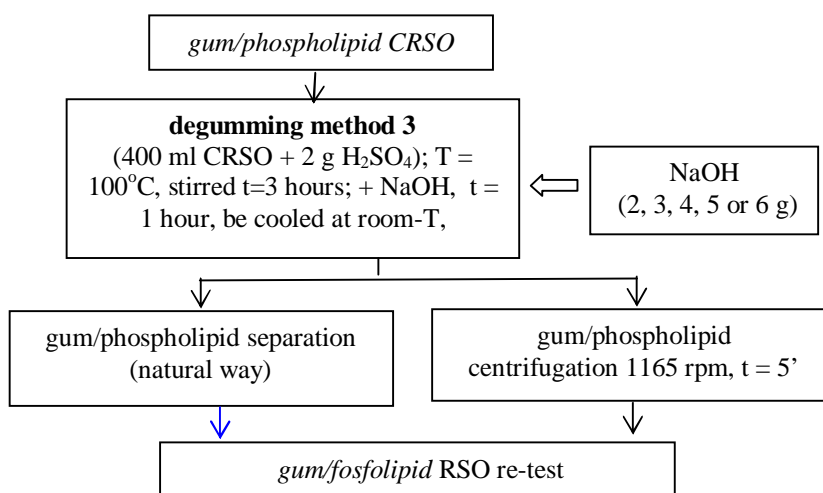


Figure 3 Flowchart of degumming process using sulfuric acid (H_2SO_4) and NaOH

Method 4: Degumming using zeolite and active carbon.

The process of degumming in this study is using zeolite and active carbon, with the ratio of zeolite, active carbon and CRSO is shown on Table 4.

Table 4 The ratio of zeolite, active carbon and CRSO

| Sample Number | Separator Material | | Mass (g) | Sulfuric Acid (H ₃ PO ₄) (ml) | NaOH (g) | CRSO | |
|---------------|------------------------------------|---------------|----------|--|----------|------|-----|
| | Ratio of Zeolite and Active Carbon | | | | | (ml) | (g) |
| | Zeolite | Active Carbon | | | | | |
| | (% w/w) | (% w/w) | | | | | |
| 1. | 100 | 0 | 40 | 0.8 | 3.2 | 400 | 360 |
| 2. | 75 | 25 | | | | | |
| 3. | 50 | 50 | | | | | |
| 4. | 25 | 75 | | | | | |
| 5. | 0 | 100 | | | | | |

CRSO in the amount of 400 ml is mixed first by 0.8 ml of phosphoric acid (H₃PO₄) and boiled up to T = 80 °C, stirred using *magnetic stirring* for t = 20 minutes, then be cooled at room-T. Add by 3.2 g of NaOH and heat it once more up to 80 °C and stir for 20 minutes. Mash zeolite and active carbon according to the ratio and filter it by mesh 80. Add such zeolite and active carbon into oil with the temperature of 80 °C and stir for 20 minutes. Let it be cooled at room temperature. The deposited of gum/phospholipid is done by two ways are naturally and centrifugation at 1165 rpm for 5 minutes. The sediment then be separated by burette. The gum/phospholipid of RSO as the result of degumming using sample 1 then be re-tested. Degumming using samples 2, 3, 4 and 5 are done with the same way. The flowchart of degumming process using zeolite and active carbon is shown in figure 4.

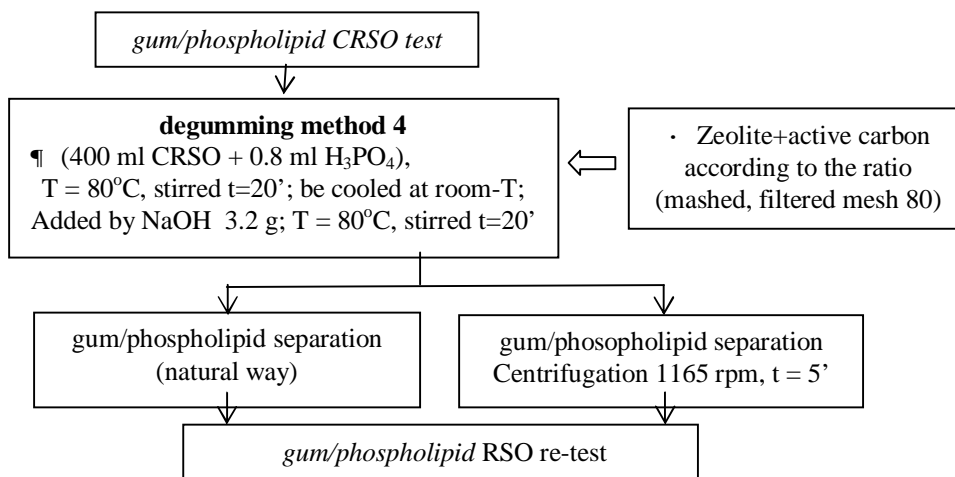


Figure 4 The degumming process using zeolite and active carbon.

III. RESULT AND DISCUSSION

3.1. Content of “gum/fofolipid”

The test results of the content of gum/phospholipid RSO before or after degumming with 4 (four) kinds of ways to experience the natural settling process and centrifuge, as well as the residue carbon content still contained shown in Table 5. In general, the content of gum/phospholipid carbon residue decreases in every way (for natural precipitation, centrifuge, and the residual carbon content). Based on data in Table 5 it appears that for natural deposition, most effective decrease of gum/phospholipid is the use of citric acid 0.5% w/w compared to use NaCl, zeolites and activated carbon or NaOH. This is caused by the properties of citric acid itself is able to reduce the content of gum/phospholipid 17.1 mg/L to 6.57 mg/L or dropped as much as 61.57%. Meanwhile, degumming using NaCl is only able to reduce gum/phospholipid by 57.7%, zeolites and activated carbon 35.79%, while NaOH 59.24%.

Based on data in Table 5 it appears that for the deposition of the centrifuge method, the most effective content of gum / phospholipid is also by using citric acid 0.5% w/w compared to use NaCl, zeolites and activated carbon and the NaOH.

The deposition by centrifuge means can reduce the amount of gum content/phospholipids in rubber seed oil as compared to the deposition of a natural method due to the centrifuge force works on oil. The centrifuge force causes the material content in the crude oil that is still very fine solids can accumulate/agglomerate into one that is more easily separated.

Table 5 The content of gum/ phospholipid rubber seed oil BEFORE and AFTER degumming with 4 methods, natural sedimentation and centrifuge sedimentation, and the test of residual carbon and the amount of sulfur (S).

| Method | Volume or Weight of rubber seed oil | Degumming material | Total of degumming material | Content test results of gum/phospholipid (mg/L) | | | The lowest decreased of gum/phospholipid content (%) | Content Test results of Carbon Residue and S After Degumming Centrifuge | |
|--------|-------------------------------------|---|-----------------------------|---|-----------------------|--------------------------|--|---|-------|
| | | | | Before degumming | After degumming | | | Carbon Residue (%) | S (%) |
| | | | | | Natural Precipitation | Centrifuge Precipitation | | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| I | 400 ml or 360 g of rubber seed oil | Natrium Clorida (NaCl) | 1.0% of the oil weight | 17.1 | 7.39 | 7.0 | Natural: Decreased by 57.7% Centrifuge : Decreased by 61.9% | 1.72 | None |
| | | | 1.5% of the oil weight | | 7.31 | 6.9 | | 1.67 | None |
| | | | 2.0% of the oil weight | | 7.29 | 6.7 | | 1.56 | None |
| | | | 2.5% of the oil weight | | 7.26 | 6.7 | | 1.47 | None |
| | | | 3.0% of the oil weight | | 7.24 *) | 6.5*) | | 1.29*) | None |
| II | 400 ml or 360 g rubber seed oil | citric acid (C ₆ H ₈ O ₇) | 0.1% of the oil weight | 17.1 | 7.18 | 6.9 | Natural: Decreased 61.57% Centrifuge : Decreased 66.1% | 0.63 | None |
| | | | 0.2% of the oil weight | | 7.17 | 6.9 | | 0.60 | 0.02 |
| | | | 0.3% of the oil weight | | 7.16 | 6.9 | | 0.57 | None |
| | | | 0.4% of the oil weight | | 7.03 | 6.6 | | 0.53 | None |
| | | | 0.5% of the oil weight | | 6.57 *) | 5.8*) | | 0.51*) | None |

Table 5 The content of gum/phospholipid rubber seed oil before and after degumming with 4 ways, the natural sedimentation and centrifuge sedimentation, as well as carbon residue test and sulfur content (S). [Sequel]

| Method | Volume or Weight of rubber seed oil | Degumming material | Total of degumming material | Content test results of "gum/ phospholipid" (mg/L) | | | The lowest decreased of gum/ phospholipid content (%) | Content Test results of Carbon Residue and S After Degumming Centrifuge | |
|--------|--|--|--|--|----------------------|--------------------------|---|---|-------|
| | | | | Before degumming | After degumming | | | Carbon Residue (%) | S (%) |
| | | | | | Natural precipitaton | Centrifuge Precipitation | | | |
| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) | (9) | (10) |
| III | 400 ml or 360 g rubber seed oil added: | Zeolites and activated carbon, total mass 40 g | Weight ratio of Zeolites: activated carbon 100 : 0 | 17.1 | 16.0 | 15.3 | Natural: Decreased by 35.79 % Centrifuge: Decreased by 40.9% | 1.04 | None |
| | | | 75 : 25 | | 16.0 | 15.0 | | 0.90 | None |

| | | | | | | | | | |
|----|--|-------------------------|----------|------|---------|-------|---|-------|--------|
| | Phosphoric acid (H ₃ PO ₄) 0.4% w/w Sodium hydroxide (NaOH) 1.6% w/w | | 50 : 50 | | 11.54 | 11.2 | | 0.73 | None |
| | | | 25 : 75 | | 10.98 * | 10.1* | | 0.66* | None |
| | | | 0 : 100 | | 13.36 | 12.0 | | 0.75 | 0.0003 |
| IV | 400 ml or 360 g rubber seed oil | Sodium hydroxide (NaOH) | 2 g NaOH | 17.1 | 7.31 | 6.9 | Natural: Decreased 59.24% Centrifuge: Decreased by 63.7% | 1.09 | None |
| | | | 3 g NaOH | | 7.15 | 6.7 | | 0.88 | None |
| | | | 4 g NaOH | | 7.07 | 6.5 | | 0.82 | None |
| | | | 5 g NaOH | | 7.06 | 6.4 | | 0.78 | 0.0026 |
| | | | 6 g NaOH | | 6.97 * | 6.2* | | 0.76* | 0.0001 |

*) = Lowest value. Permissible residual carbon content in biodiesel according to the standard of FBI 2005 for 10% of distillation residue is 0.3%. Results of previous studies 2.87%^[1,2]

Especially for residual carbon content, the four degumming method can reduce the content of gum/phospholipid but the most effective is the use of citric acid degumming 0.5% w/w. The value of residual carbon rubber seed oil after degumming is 0.51%. This value is still higher than the maximum terms specified in the standard FBI in 2005 amounted to 0.3% (for 10% of distillation residue) because it has not undergone the process of making biodiesel with a non-catalytic superheated method atmospheric pressure methanol using reactor BCR. But indirectly hinted that this value had decreased significantly from the results of previous studies that have been done namely 2.87%.^[1,11] Content of sulfur (S) is none or almost all of the samples have zero values (0 %), except for citric acid 0.2 % w/w still contains sulfur 0.02 %, zeolites and activated carbon 0.0003 %, sodium hydroxide 0.0026 %; although has not become biodiesel but had been under FBI standards in 2005 (the maximum allowable levels of S in biodiesel is 0.05 %).

3.2 Biodiesel Quality

The best rubber seed oil (RSO) which has undergone a process of degumming in this case is that one which has undergone degumming of citric acid 0.5% w/w then processed into biodiesel with a non-catalytic method “*superheated methanol bubble column reactor*” low pressure with a molar ratio between methanol and rubber seed oil of RM = 160. The optimum reaction temperature in BCR 290 °C.^[1,11,12] Comparison of results of quality testing of biodiesel (B100) between the non-catalytic without degumming and that has experienced degumming of Citric acid and centrifuge deposition shown in Table 6.

Based on the data in Table 6, it appears that all of the parameters that exist in the standard of PBI 2005 have been fulfilled by rubber seed biodiesel which has undergone degumming process of citric acid (C₆H₈O₇) 0.5% w/w, centrifuge sedimentation is rotated in round 1165 rpm for 5 minutes and processed in a non-catalytic *superheated* highest temperature of methanol (290 °C) atmospheric pressure using reactor BCR and molar ratio RM = 160.

Specifically for cetane number (*cetane number*), rubber seed biodiesel have numbers of *Calculated Cetane Index* (CCI) 47.5. To calculate the number of the cetane then the value of CCI is added by 2 to 3.^[13] So, cetane number = 47.5+3 = 50.5. ASTM D6751-06 states that the minimum cetane number 47. Whereas ASTM D4737-96a requires the value of CCI minimum 45. Based on the SK Dirjen MIGAS no. 3675.K/24/DJM/2006 date of March 17 2006 states that for solar, minimum cetane number is 48 tested based on the method of ASTM D-613 or CCI minimum of 45 by test method of ASTM D4737-96a. Thus it is clear that this biodiesel is ready to be marketed if refers to the standard of FBI in 2005 and SK Dirjen Migas RI no. 3675.K/24/DJM/2006.

Table 6. The test results difference of biodiesel (B100) between non-catalytic method without degumming and via degumming citrate acid and centrifuge

| No.. | Quality of Biodiesel based on FBI Standard in 2005 | | | | ASTM Method | Test Results of Biodiesel Non-Catalytic Method | |
|------|--|-------------------|-------|-------------|-------------|--|--|
| | Chemical Properties | Units | Range | | | Without Degumming ^[12] | Degumming and Centrifuge ^{*)} |
| | | | Min | Max | | | |
| 1. | Density at 15°C | kg/m ³ | 850 | 890 | D-1298 | 882 | 886 |
| 2. | Kinematic Viscosity (40°C) | cSt | 2.3 | 6.0 | D-445 | 5.19 | 4.57 |
| 3. | Cetane Number | | 51 | - | D-613 | 47.5 | 44.7 |
| 4. | Pour Point | °C | - | 18 | D-97 | -6 | 2 |
| 5. | Flash Point | °C | 100 | - | D-93 | 200 | 125 |
| 6. | Copper strip corrosion (3 hours at 50°C) | ASTM Number | - | No.3 | D-130 | No.1.b | No.1a |
| 7. | Carbon Residue in • 100% pure example • 10% deposit distillation | % mass | - | 0.05 0.3 | D-4530 | 0.126 2.87 | 0.29 |
| 8. | Water and Sediment | % vol | - | 0.05 | D-2709 | 0.01 | 0.01 |
| 9. | 90% Distillation Temperature | °C | - | 360 | D-1160 | 347 | 338 |
| 10. | Sulfated ash | % mass | - | 0.02 | D-874 | 0.01 | - |
| 11. | Sulfur | % mass | - | 0.05 | D-5453 | 0.72 | Zero (0) |
| 12. | Acid Number | mg-KOH/g | - | 0.8 | D-664 | 0.01 | 0.783 |
| 13. | Free Glycerin | % mass | - | 0.02 | D-6584 | ND | - |
| 14. | Total Glycerin | % mass | - | 0.24 | D-6584 | ND | 0.216 |



CCI = 454.74 - 1,641.416 D + 774.74 D² - 0.554 B + 97.803 (log B)²
which:
D = density at 15°C, g/ml
test method D 1298 or D 4052
B = mid boiling temperature °C
(test result is 333 °C, see B-2 List)

Heating value = (12400 - 2100 SG²) x 1.8 BTU/lbm, which SG = Specific Gravity

Color Test of biodiesel ASTM D 1500-98 standard in PT Pertamina is 2.5, (max.3.0, is met).

Non-Catalytic Method was better than Catalytic Method; met with ASTM D6751-06; but not met with FBI 2005 standard yet.

3

*) Citric acid Degumming (C₆H₈O₇) 0.5% w/w; Centrifuge precipitation in round of 1165 rpm, rotated for 5 minutes. T reaction = 290 °C, RM = 160.

IV. CONCLUSION

Based on the analysis of data it can be concluded such as below: Through additional preliminary process namely degumming, it can reduce levels of carbon residue and sulfur contained by the rubber seed oil or biodiesel of rubber seed processed through non-catalytic method "superheated methanol" atmospheric pressure inside the reactor of BCR. The best material for degumming to lower the content of gum/phospholipid CRSO as well as rubber seed biodiesel is Citric acid (C₆H₈O₇) 0.5 % w/w. Precipitation by means of centrifuges can minimize the content of gum/phospholipid in a rubber seed oil compared to precipitation naturally due to the centrifuge force works on oil. The centrifuge force causes the material content in the crude oil that is still very fine solids can accumulate/agglomerate into one that is more easily separated. Biodiesel produced in accordance with the standards of FBI 2005 and ready for the market through gas stations.

V. ACKNOWLEDGEMENT

For the implementation of this research, we thank you profusely to the Director of DP2M Higher Education (now Director of Research and Community Service Kemenristekdikti) who has given credence to the research team. Our gratitude also goes to the Director of PIU IDB "Seven in One" which has provided funding for this research activity. Hopefully the results of this research benefit us all. Amien.

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