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Optimal Treatment Combination for Dishwashing Liquid Soap based on Waste Cooking Oil According to The Requirement of Indonesian Quality Standards

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Abstract: Much waste cooking oil (WCO) is still discarded even though it can be processed into more valuable products, such as dishwashing liquid soap. The quality of dishwashing liquid soap made from WCO is influenced by the method used, the concentration of potassium hydroxide (KOH) and the adsorption material used. Variations of these three variables produce different qualities. Soap quality is measured based on PH, free alkalis and fatty acids produced. This study uses an experimental design to produce the best combination. The results of the combination will be checked for conformity with the quality standards of SNI 06-2048-1990. The best treatment combination is the cold method, 22.5% KOH concentration, activated carbon purification material with a pH value of 9.00, 0.05 free alkalis, and 0.32 free fatty acids. The soap products produced are in accordance with Indonesian quality standards and generate profits economically.

Keywords: dishwashing liquid soap; waste cooking oil; experiment design

1. Introduction

Oil palm can only grow in the tropic region with very high rainfall, such as in Indonesia[1,2,3]. The Indonesian Palm Oil Association noted that domestic consumption of palm oil in the first semester of 2020 was 8.66 million tons. This number has increased by around 2.8% in the same period in 2019. Meanwhile, more than 90% of households in Semarang still dispose of waste cooking oil and have not yet recycled. This amount is equivalent to 252,271 liters of WCO which is discharged annually[4,5]. Reconsuming waste cooking oil will endanger food safety and human health[6]. However, if used cooking oil is thrown away, the WCO will damage the aquatic ecosystem[7]. This is due to the oil layer in the water that will cover the surface and inhibit oxygen to diffuse[8]. At present, there have been many studies that have succeeded in processing waste cooking oil into various products, for example, biodiesel[9,10]. There are using waste chicken eggshell derived cao as a catalyst via transesterification [11], using the homogeneous base catalyst and methanol[12], and using green solid catalyst derived from calcined fusion waste chicken and fish bones[13]. Nabilla et al using a dielectric barrier discharge non-thermal plasma reactor without chemical catalysts and the formation of unwanted co-product such as glycerin and soap[9]. However, biodiesel still has some technical problems such as low-temperature, oxidative stability, nitrogen oxides emissions, and insoluble impurities causing fuel filter clogging[14]. Waste cooking oil also can be processed into soap[15] products to increase its economic value and to reduce environmental impact. Utilizing waste into valuable products will reduce negative environmental impact[16,17,18,19].

This research intends to make products that are more valuable with the basic ingredients of WCO. This study conducted a random survey in Semarang with 133 respondents. The survey results stated that 82% welcomed it if WCO was processed into soap. As many as 76% prefer dishwashing liquid soap to solid soap, and 60% of respondents choose the type of dish soap compared to handwashing soap/shower soap.

Waste cooking oil used for making dishwashing liquid soap is usually cooking oil with three times usage. Waste cooking oil must be purified before being processed into soap[20]. One study that examined the manufacture of liquid soap from waste cooking oil research using a completely randomized design with a single factor, KOH concentration consisting of 3 levels, namely 25%, 30%, and 35%[8]. The characteristics of liquid soap observed were viscosity, high foam, pH, and free alkali content. In the previous study[21], the study only uses a single factor, namely the concentration of KOH. Use a semi-boiling method and activated carbon purification materials, so the effect of various manufacturing methods and the effect of different purification materials are not yet known. Also, the observation of the characteristics of liquid soap has not observed the amount of free fatty acids contained in liquid soap that is included in one of the soap quality parameters according to the Indonesian National Standard (SNI). The results showed that the most optimal KOH concentration was 25% with a pH value of 10.3 and free alkali values of 0.0847%. Based on these results it can be seen that the results of the soap characteristics obtained are close to the maximum limit of soap quality provisions by SNI 06-2048-1990 (National Standardization Agency, 1990) which is 11 for pH and 0.14% for free alkali. In this study, the most optimal KOH concentration is obtained from the lowest concentration results, so it is necessary to measure the characteristics of the soap using a comparison of lower KOH concentrations than the results of previous studies and then make a comparison to find out which formula is better.

2. Research Method

Waste cooking oil for the manufacture of dishwashing liquid soap is household cooking oil with three uses[22]. The results of a questionnaire that was conducted to the Semarang City community concluded that the processing of waste cooking oil is better processed into dishwashing liquid soap with physical characteristics colored and smelled of herbal scents. The results of processing waste cooking oil into dishwashing soap will be tested by referring to the SNI 06-2048-1990 quality standards on laundry soap. The tools and materials used consist of household waste cooking oil with 3 (three) times usage, activated carbon, kepok banana peels, water, oil filter paper, scales, plastic cups, KOH, food coloring, fragrance, hand blender, water thermometer, dropper glass, syringes, heat/stainless steel containers, denatured alcohol, alcohol Bunsen lamps, wire mesh, Erlenmeyer measuring flask, stirring rod, alcohol 96%, HCL 0.1 N KOH 0.1 N, Indicator phenolphthalein 1% and pure water [21].

The experimental design is used to find the key parameters of the forming process and their optimal values[23,24]. This study using experiment design to find a combination of manufacturing methods, purification materials, and different base concentrations that meet the SNI quality test standards for soap consisting of three parameters namely free alkali levels, free fatty acids, and soap pH. The manufacturing method consists of the cold method (A1) and the semi-boiling method (A2). The concentration of KOH with concentrations of 22.5% (B1), 25% (B2), and 27.5% (B3), as well as the purification of activated carbon (C1) and kepok banana peels (C2). This treatment combination was chosen by considering the possible effect of the treatment on the SNI parameters used based on previous research. Table 1 shown the combination of the treatment of making dishwashing liquid soap from WCO.

2.1. Purification of Waste Cooking Oil

Waste cooking oil is purified before being used to make soap. The stages of the purification process include filtering to separate despising and the immersion process[25]. Filtering is done using filter paper and soaking process using 7.5 grams of activated charcoal[26] and 100 grams of kepok banana peel as an adsorbent with a 24-hour immersion time [27].

2.2 Making Dishwashing Liquid Soap

The making of dish soap consists of two methods. The cold method is made by mixing 100 grams of waste cooking oil with KOH concentrations of 22.5%, 25%, and 27.5%. Then stir using the hand blender for 45 minutes. After that water is added with a ratio of water: soap 2 : 1. Stir again for 3 minutes then add coloring and perfume as much as 2 mL then stir for 2 minutes[25]. In the semi-boiling method, the manufacturing process is the same as the cold method, the difference is waste cooking oil is preheated until it reaches a temperature of 55ºC, then mixed between KOH and oil using ratio 2:1 (100 grams of waste cooking oil and 50 grams of KOH)[21].

Table 1. The Combination of the Treatment of Making Dishwashing Liquid Soap from WCO.

Combination	Description
$A_1B_1C_1$	Cold method + 22,5% KOH + Activated Carbon
$A_1B_1C_2$	Cold method + 22,5% KOH + Kepok banana peels
$A_1B_2C_1$	Cold method + 25% KOH + Activated Carbon
$A_1B_2C_2$	Cold method + 25% KOH + Kepok banana peels
$A_1B_3C_1$	Cold method + 27,5% KOH + Activated Carbon
$A_1B_3C_2$	Cold method + 27,5% KOH + Kepok banana peels
$A_2B_1C_1$	The semi-boiling method + 22,5% KOH + Activated Carbon
$A_2B_1C_2$	The semi-boiling method + 22,5% KOH + Kepok banana peels
$A_2B_2C_1$	The semi-boiling method + 25% KOH + Activated Carbon
$A_2B_2C_2$	The semi-boiling method + 25% KOH + Kepok banana peels
$A_2B_3C_1$	The semi-boiling method + 27,5% KOH + Activated Carbon
$A_2B_3C_2$	The semi-boiling method + 27,5% KOH + Kepok banana peels

2.3 Dishwashing Liquid Soap Test

SNI parameters used to consist of pH, free alkali, and free fatty acids. PH measurement is carried out using a pH meter. Measurement of free alkali and free fatty acids is done by titration[21]. A free alkali test was carried out by mixing 10 grams of dishwashing liquid soap into 96% alcohol as much as 25 mL in a 100 mL Erlenmeyer measuring flask. Then add 3 drops of 1% phenolphthalein indicator. Titrate with 0.1L HCL until the pink color disappears. Record the volume of 0.1 N HCl used by the plates[28]. Whereas the free fatty acid test was carried out by mixing 5 grams of dishwashing liquid soap into 96% alcohol as much as 25 mL in a 100 mL Erlenmeyer measuring flask. Heat the sample to a boil. Then add 3 drops of 1% phenolphthalein indicator. Titrate with 0.1 N KOH until a pink color appears that does not change for 15 seconds. Record the volume of 0.1 N KOH used[28].

2.4 Data Analysis

The data obtained were analyzed using a normality test, homogeneity test, and univariate multi-way anova test. The normality test is a test that aims to assess the distribution of data whether or not it is normally distributed in a group of data or variables (Ghozali, 2009). The homogeneity test aims to determine whether the variance of the quality standard test results in each treatment has the same variance or not. If the value of Sig $<\alpha$ then the hypothesis is rejected and if Sig$> \alpha$ then the hypothesis is accepted. If the test results are not homogeneous, then the sample cannot be used and needs to be re-evaluated to get a homogeneous sample (Sudjana, 2005). The interaction test between factors is carried out to determine whether there is an influence caused by a combination of factors on the response. This test consists of two-way interactions and three-way interactions (Widiyanto, 2013).

Furthermore, the Tukey test was carried out with a confidence level of 95% ($\alpha = 0.05$) using SPSS software to determine the significant differences between the combination of the test results.

3. Result and Discussion

3.1. Data Analysis

Based on the results of the normality test, the homogeneity test and the univariate multi-way anova test (Three-Way Anova) showed that there were no significant differences between treatment combinations. However, it was found that the manufacturing method and KOH concentration influenced the pH value contained in dishwashing liquid soap, where the semi-boiling method produced a higher pH than the cold method, and the higher the KOH concentration, the pH value also increased. Similar results were demonstrated by previous research[21]. In that study, the dishwashing liquid soap tested had 25%, 30%, and 35% KOH concentrations. In pH testing it was found that the KOH concentration had a significant effect on pH, the higher the KOH concentration the higher the pH value of the resulting dishwashing liquid soap. 25% of KOH concentration produced the best soap with a pH value of 10.30. Whereas in this study the best KOH concentration was 22.5% having a lower pH value of 8.97. This happens because of the difference in the mixing time used in the soap making process. This study used a smaller KOH content than previous studies, namely 22.5% and resulted in a smaller pH value, namely 8.97. The resulting pH value accords to the SNI requirements because it is between 8 - 11. The previous research using a KOH concentration of 25% produced the best soap with a pH value of 10.30.

In the free alkali parameters, it was found that the factor of KOH preparation method and concentration influenced the value of free alkali contained in the soap, where the semi-boiling method produced higher free alkali compared to the cold method and the higher the KOH concentration, the value of free alkali also increased. Similar results were demonstrated by research conducted by Silsia, Susanti, and Apriantonedi[21]. In that study it was found that the concentration of KOH had a significant effect on free alkali, the higher the KOH concentration the higher the value of the free alkali liquid soap produced. Similar results were also shown by Prihanto and Irawan[20].The results showed that increasing the concentration of NaOH would increase the levels of free alkali present in the soap. This happens because the greater the concentration of NaOH added, the more NaOH is added so that more NaOH is left from the lathering reaction. The remaining NaOH from this saponification reaction is found in soap as free alkali. In the research results, Silsia, Susanti, and Apriantonedi[21], 25% KOH concentration produced the best soap with a free alkali value of 0.0272. Whereas in this study it was found that the concentration with the lowest free alkali value was at a concentration of 22.5% with the free alkali content obtained at 0.0598. This difference occurs because of the different mixing times used in the soap making process and the manufacturing method.

In the free alkali parameters, it was found that the manufacturing method and purification factor influenced the value of free fatty acids contained in the soap, where the semi-boiling method produced higher free fatty acids compared to the cold method and the activated carbon purification material was better than the Kepok banana peel because resulting in lower free fatty acid values. In this research, waste cooking oil used is the oil with three times usage. According to Pratiwi and Setyaningsih[28] waste cooking oil with three times the purified use of activated carbon-containing free fatty acids was 0.28%, while in this study the highest activated carbon was 0.5717%. This difference occurs because of differences in the process of making soap and the process of refining waste cooking oil.

3.2 Effect of Combination Treatment on the pH of the soap

The average pH produced is between 8.97-9.33. This pH value has fulfilled the SNI standard for laundry detergent that is with pH 8-11. The results of the study showed that the pH value was influenced by the method of making and KOH concentration. The pH value in the cold method is lower than the semi-boiling method. The higher the KOH concentration the higher the pH value. A comparison diagram of pH values between treatment combinations can be seen in Figure 1.

This study used a smaller KOH content than previous studies, namely 22.5% and resulted in a smaller pH value, namely 8.97. The resulting pH value accords to the SNI requirements because it is between 8 - 11. The previous research[21)] using a KOH concentration of 25% produced the best soap with a pH value of 10.30.

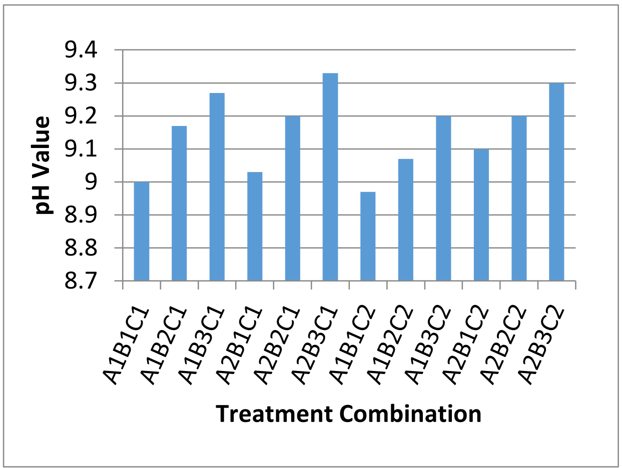

Figure 1. Comparison Diagram of pH Values between Treatment Combinations

3.3 Effect of Combination Treatment on Free Alkali Levels

The average free alkali produced is between 0.05% - 0.09%. The value of free alkali has met the SNI standard of laundry soap that is a maximum free alkali content of 0.15% for liquid soap. The results showed that the value of free alkali was influenced by the method of making and KOH concentration. The free alkali value in the cold method is lower than the semi-boiling method. The higher the KOH concentration the higher the free alkali value. Comparison Diagram of Free Alkali Levels between Treatment Combinations can be seen in Figure 2.

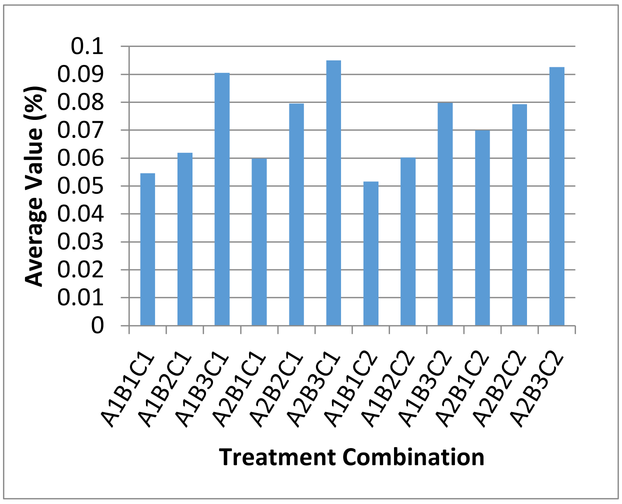

Figure 2. Comparison Diagram of Free Alkali Levels between Treatment Combinations

3.4 Effect of Combination on Treatment of Amount of Free Fatty Acid

Average free fatty acids produced between 0.3243% - 0.5717%. The amount of free fatty acids has met the SNI standard for laundry soap, with a maximum value of 2.5%. The results showed that the value of free fatty acids was influenced by the method of preparation and purification. The value of free fatty acids in the cold method and activated carbon is lower than the semi-boiling method. Comparison Diagram of Free Fatty Acids between Treatment Combinations can be seen in Figure 3.

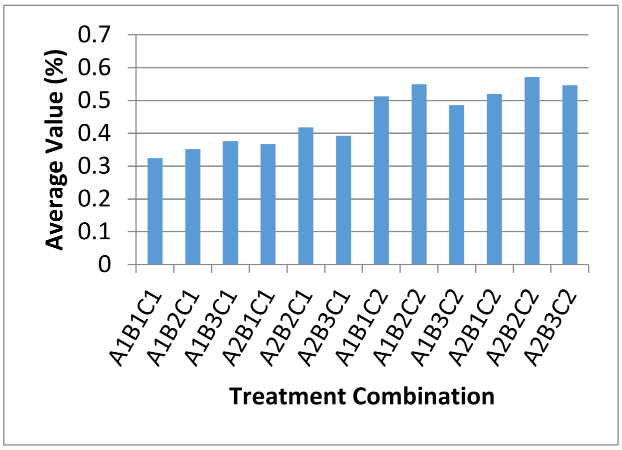

Figure 3. Comparison Diagram of Free Fatty Acids between Treatment Combinations

3.5 Cost Analysis

The study also conducted an economic feasibility analysis if soap making was carried out on a small scale by the Family Welfare Empowerment Team (FWET). Production is assumed to be made by FWET so it does not require labor costs. The depreciation value of the tool uses the straight-line method[29)] with a lifetime of about 5 years.

Capital costs are assumed to be borrowed from banks with an interest rate of 7% per year. The annual production capacity about 2400 products (volume 400 ml/product). The cost of goods sold is calculated based on material costs, equipment costs, overhead costs, and marketing costs. In detail, the cost of goods sold is shown in Table 2.

Table 2. The Cost of Goods Sold

Item	Unit of Measure	Amount (unit)	Total Cost (IDR)
A. Raw Material Cost			
Oil filter paper	Sheet	1,200	1,800,000
Fragrance	mL	4,800	2,016,000
Food coloring	mL	4,800	608,000
Potassium hydroxide	Gram	60,000	855,000
Activated carbon	Gram	60,000	545,455
Plastic packaging	Pieces	2,400	372,000
Waste cooking oil	Liter	4,800	7,200,000
Subtotal			13,396,455
B. Equipment Cost			
Hand blender	Pieces	4	520,000
Balance	Pieces	1	925,000
SS container	Pieces	1	19,000
SS spoon	Pieces	2	3,000
Plastic container	Pieces	2	26,000
Gloves	Pieces	12	180,000
Face Masks	Pieces	12	240,000
Eyeglasses	Pieces	12	360,000
Subtotal			1,440,500
C. Labor Cost			0
Overhead Cost			
Utilities D.(electricity and water)			600,000
Building Rent			2,400,000
Depreciation Cost			288,100
Sub Total			3,288,100
Marketing Cost			1,027,500
E. Total Cost (A+B+C+D+E)			19,152,555
Total Capacity	Unit		2,400
COGS/unit			7,980

Table 3 contains information about determining the selling price in making dishwashing liquid soap from waste cooking oil.

Table 3. Determination of Selling Prices

Basic Selling Price / Unit		IDR	7,980
Desired profit		5%	
Selling price / unit		IDR	8,379
Selling Price in the Supply Chain	Retail Selling Prices from Wholesalers	IDR	8,798
	Retail Selling Price from Retail	IDR	8,966

4. Conclusion

All treatment combinations had fulfilled the SNI wash quality standards for SNI 06-2048-1990. The pH value and free alkali content are influenced by a combination of treatment and KOH concentration. Free pH and alkali values in the cold method are lower than the semi-boiling method. The pH and free alkali values are affected by the KOH concentration. The higher the KOH concentration, the higher the PH and free alkane values. Meanwhile, the amount of free fatty acids is influenced by the method of manufacture and purification. The amount of free fatty acids in the cold method and activated carbon is lower compared to the semi boiling method and kepok banana peel. The best combination of treatments is A1B1C1 (cold preparation method, 22.5% KOH concentration, activated carbon purification material) with a pH value of 9.00, free alkali 0.05, and free fatty acids 0.32. The economic benefit of converting WCO to soap is relatively small. However, this effort can increase the added value of WCO, can reduce the negative impact of WCO on the environment as well as empower people to increase waste into products that are more valuable while saving the environment.

The theoretical contribution of this research is to enrich the study of making dish washing liquid soap from waste cooking oil using three independent variables. Previous research used only one independent variable[21]. This study provides managerial contributions to the management of WCO to reduce negative environmental impacts as well as provide benefits to the economic aspect.

Weaknesses of this study have not considered the effect of storage time and the possibility of using natural ingredients for dyes and deodorizers. Further studies need to be carried out on the minimum and maximum limits of the composition of cooking oil soap making materials soap using both experimental designs and statistical models so that manufacturing time can be shortened and the cost of soap production can be reduced. In the next research, marketing strategy planning and product socialization can be carried out so that people are interested in using processed waste cooking oil products and can compete with other competitors' products.

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