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Effect of Variation of Cocamide DEA, Activated Carbon, and Addition of Orange Peel Extract on the Characteristics of Liquid Hands Soap from Cooking Oil

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ABSTRACT

The reuse of used cooking oil poses health risks, while its disposal contributes to environmental pollution. One sustainable alternative is to utilize used cooking oil as a raw material for the production of hand washing liquid soap. In this study, hand washing liquid soap was formulated using purified used cooking oil. Additional ingredients included cocamide DEA, a surfactant that enhances foam stability, and activated carbon, which improves the soap's cleaning effectiveness. The research involved two main stages: the purification of used cooking oil and the formulation of the liquid soap. The purification process consisted of three steps—removal of spices and impurities, neutralization, and bleaching. The soap-making process involved saponifying the purified oil with a potassium hydroxide (KOH) solution, followed by dilution of the soft soap with distilled water. The final formulation stage included the addition of cocamide DEA and activated carbon. The results demonstrated that the final product met acceptable quality standards, with a suitable pH level, low levels of free alkali and free fatty acids, and satisfactory foam stability and cleaning performance. These findings indicate that liquid hand soap derived from used cooking oil is not only feasible but also represents an eco-friendly alternative for waste oil management and hygiene product development.

***Keywords**: used cooking oil, liquid soap, cocamide DEA, activated carbon*

1. INTRODUCTION

The food industry, hospitality sector, restaurants, and households are the primary sources of waste in the form of used cooking oil, resulting from repeated usage. This used oil, commonly referred to as **waste cooking oil**, poses serious health risks when reused for consumption, as it contains harmful oxidation products such as peroxides, aldehydes, and free fatty acids. On the other hand, improper disposal of waste cooking oil without adequate treatment can lead to significant environmental pollution. Therefore, converting waste cooking oil into high-value products, such as liquid soap, offers an effective and sustainable solution. Liquid soap is considered more practical, hygienic, and economical compared to bar soap.

The demand for soap in Indonesia continues to rise. According to data from the Central Statistics Agency (Badan Pusat Statistik, BPS), soap consumption increased from 55,832 tons in 2009 to 101,631 tons in 2014. This growing demand highlights the potential for producing soap using waste cooking oil as the primary raw material. Bidilah (2017) demonstrated that liquid soap made from waste cooking oil meets the quality standards of commercial liquid soap based on parameters such as pH, free alkali content, and free fatty acid levels, with values of

pH 10, 0.01% free alkali, and 0.14% free fatty acids, respectively. However, the resulting foam stability remains relatively low, ranging between 40–50%.

According to Cholifah et al. (2021), foam stability is considered acceptable when it reaches 60–70% after five minutes. To enhance this characteristic, the incorporation of additional ingredients such as **cocamide DEA** is necessary. Cocamide DEA is a nonionic surfactant known for its ability to increase viscosity and foam stability without causing skin irritation, making it safe for use even on sensitive skin. In addition, **activated carbon** is another promising additive that can improve cleansing power. Activated carbon functions through adsorption, allowing it to bind and remove impurities effectively.

In this study, a combination of cocamide DEA and activated carbon was used in the formulation of liquid soap from waste cooking oil. This specific combination remains underexplored, particularly in the context of handwashing soap. The formulation also includes **orange peel extract**, which serves as a natural antibacterial agent, foam stabilizer, and fragrance enhancer. Orange peels are known to contain phenolic compounds and tannins, which exhibit antimicrobial activity by disrupting the cell membrane permeability of microorganisms.

According to data from the Indonesian Palm Oil Association (GAPKI), domestic palm oil consumption in 2021 exceeded 18 million tons. This indicates a vast potential for waste cooking oil that could be repurposed. One promising utilization pathway is the production of liquid soap from such waste, offering an environmentally friendly and cost-effective alternative while contributing to waste reduction.

Nonetheless, liquid soap derived from waste cooking oil still presents limitations, particularly in terms of foam stability and cleansing efficiency. Therefore, the addition of cocamide DEA as a foam-stabilizing surfactant (Andersen, 1996), activated carbon as a dirt-adsorbing agent (Lestari et al., 2020), and orange peel extract as a natural antibacterial agent (Dewi, 2014) is essential. This study investigates the combined effects of these three additives on the quality of liquid soap.

2. METHODS

The research method is carried out with the type of empirical research. The research was conducted at the Bandung State Polytechnic Chemical Engineering Laboratory. The main ingredient used in this research is used cooking oil. The tools used in this study included hot plates, beakers, thermometers, pH meters, turbidimeters, and ovens. The variables in this study are as follows:

A. Controlled Variables

The refining process of waste cooking oil and the extraction process of orange peel were conducted under constant operating conditions without variation. The controlled variables in the liquid soap production process include the amount of refined waste cooking oil, the quantity and concentration of KOH, and the time and temperature during soap production.

B. Independent Variables

- **Variation in the amount of activated carbon** relative to the total amount of other raw materials:
  1:97 (F1), 0.75:97 (F2), 0.5:97 (F3), and 0.25:97 (F4)
- **Variation in the combination of cocamide DEA and activated carbon**, with the ratio of cocamide DEA:activated carbon:other raw materials being: 1:0.25:97 (F5), 2:0.25:97 (F6), and 3:0.25:97 (F7)
- **Variation in the amount of orange peel extract**, with the ratio of orange peel extract:cocamide DEA:activated carbon:other raw materials being: 1:2:0.25:97 (F8) and 2:2:0.25:97 (F9)

The stages of the research process are as follows:

2.1. Purification of Used Cooking Oil

The purification process of used cooking oil was carried out in three main stages: despicing, neutralization, and bleaching. In the despicing stage, 500 mL of used cooking oil was mixed with 500 mL of water and heated until the water volume was reduced by half. The oil layer was then separated using a separating funnel, followed by filtration with filter paper to remove solid impurities. During the neutralization stage, the filtered oil was reheated and treated with a 4.23 M (15%) potassium hydroxide (KOH) solution. The mixture was subsequently filtered to separate the resulting precipitates. In the bleaching stage, the neutralized oil was heated to 70°C, and activated carbon powder was added at an oil-to-carbon ratio of 1:10 under continuous stirring. The mixture was then reheated to 100°C, and the final purification was achieved through filtration.

2.2. Extraction of Orange Peel

The orange peel extraction process began with washing and cutting the peels into 2 cm × 2 cm pieces, followed by oven drying at 60°C for 24 hours. The dried peels were ground using a grinder until a particle size of 70 mesh was achieved. The resulting powder was mixed with 96% ethanol at a ratio of 1:10 (w/w). The extraction was conducted at 28 ± 2°C with continuous stirring for 2 hours. The solution was filtered using filter paper to separate the solid residue, and the extract was subsequently isolated from the solvent using a rotary evaporator.

2.3. Production of Liquid Hand Soap

Liquid hand soap was formulated based on the method developed by Bidilah et al. (2017), with several modifications. Initially, the refined used cooking oil was combined with KOH and stirred for 40 minutes while being heated to 80°C. The saponification process was considered complete upon reaching the trace stage, characterized by the ability to form visible lines in the mixture, indicating the complete

reaction of oil with the base. The soft soap was then allowed to rest at room temperature for one hour.

The dilution process was performed by reheating the soap until it became transparent, followed by the addition of distilled water. Activated carbon was incorporated at 25°C, and cocamide DEA was added at 40°C, both with continuous stirring to ensure homogeneity. The best-performing formulation was identified based on optimal pH (ranging from 4 to 10), foam stability (minimum 60%), and effective cleansing ability. Using this optimized formulation, orange peel extract was added in varying concentrations at the final stage, as detailed in Table 1.

Table 1. Variation Concentrations

Ingredient Name	F1	F2	F3	F4	F5	F6	F7	F8	F9
Used Cooking Oil	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8	13.8
36% KOH Solution	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4
Activated Carbon	1	0.75	0.25	0.25	Result of activated carbon use	best carbon	Result of carbon and cocamide DEA mix	Result of carbon and cocamide DEA mix	
Cocamide DEA	0	0	0	0	1	2	3	1	2
Distilled Water (Aquadest)	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8	70.8
Orange Peel Extract	0	0	0	0	0	0	0	1	2

2.4. Analytical Procedures

Post-production analysis was conducted to evaluate the physicochemical properties of the liquid soap and to ensure conformity with Indonesian National Standard (SNI) 2588:2017. The analyses were categorized as follows:

1. **Analysis of Used Cooking Oil (Pre- and Post-Purification):**
   - *Free Fatty Acid Content:* Measured to assess the level of hydrolysis in the oil before and after purification.
   - *Moisture Content:* Determined to evaluate water content and potential for microbial growth.
2. **Analysis of Orange Peel Extract:**
   - Qualitative tests were conducted to confirm the presence of bioactive compounds such as tannins and saponins.
3. **Evaluation of Soap with Varying Activated Carbon Content:**
   - Characterization included pH measurement and cleansing effectiveness.
4. **Evaluation of Soap with Cocamide DEA and Activated Carbon Combinations:**
   - Foam stability and pH were analyzed to assess the impact of cocamide DEA as a foam stabilizer.
5. **Evaluation of Soap with Varying Orange Peel Extract Additions:**
   - The effect on pH and foam stability was evaluated to determine compatibility with the base formulation.
6. **Final Analysis of Optimized Soap Formula:**
   - The free alkali content was quantified using titration with 0.1 N HCl to determine the amount of unreacted base (alkali residue), and the results were compared against SNI 2588:2017 limits.

3. RESULTS AND DISCUSSIONS

This study began with the purification process of used cooking oil. The analysis results of the used cooking oil before and after purification are presented in Table 2.

Table 2. Analysis of Used Cooking Oil Before and After Purification

Test Parameter	Used Cooking Oil	Purified Oil	SNI Standard

Free Fatty Acid (mg KOH/g)	0.434548	0.127808	Max. 0.3 mg KOH/g
Water Content (% w/w)	0.204	0.135	Max. 0.15 % w/w
Color	Yellowish brown	Clear yellow	Normal

Based on Table 2, it can be seen that the purified used cooking oil shows a significant reduction in both free fatty acid and water content, along with a visible colour change to clear yellow. These parameter values meet the quality standards for cooking oil according to SNI.

Orange peel extraction was carried out using the maceration method by soaking orange peel powder in 96% ethanol for 24 hours. During this process, diffusion occurs between the solvent and the active compounds, whereby the higher-concentration solution is displaced by the lower-concentration solvent until concentration equilibrium is reached. From 100 grams of orange peel powder, an extract yield of 32.48% was obtained.

The resulting extract was then qualitatively tested to detect the presence of tannins and saponins. The tannin test involved adding FeCl3, which produced a greenish-black color due to the formation of a complex between tannins and Fe3+ ions. Meanwhile, the saponin test showed foam formation, resulting from glycosides undergoing hydrolysis and producing glucose and foam. Hydrolysis using HCl was conducted to break the glycosidic bonds within the compounds.

Next, variations in activated carbon addition were performed to evaluate its effect on the pH and cleansing power of the liquid soap. The pH measurement results are presented in Table 3.

Table 3. Liquid Soap pH Analysis

Addition Various Activated Carbon	
Formula	pH
F0	8.09
F1(1)	8.76
F2(0.75)	8.72
F3(0.5)	8.62
F4(0.25)	8.56

Table 3 shows that the addition of activated carbon increases the pH of the liquid soap. Nevertheless, all pH values remain within the acceptable range specified by SNI 2588:2017.

This increase in pH may be attributed to the presence of basic impurities adsorbed on the surface of the activated carbon.

Soap cleaning effectiveness was assessed by comparing turbidity (NTU) values of rinse water before and after use. The results indicated that the soap formula without activated carbon (F0) exhibited lower turbidity than formulas F1 to F4. Higher turbidity of the rinse water signifies more dirt being removed, indicating improved soap effectiveness. Activated carbon contributes to this effectiveness by adsorbing impurities through its porous structure. However, excessive use of activated carbon may reduce effectiveness due to its overly adsorptive nature, which can also capture active compounds in the soap.

Table 4. The Effectiveness of Liquid Soap

Sample	Dilution Soap		Variation Oil		Difference (NTU)
	p1 (NTU)	p2 (NTU)	p1 (NTU)	p2 (NTU)	
F0	3,23	9,74	153,6	145,9	146,508
F1	138	143,2	206,8	201,9	63,75
F2	132,9	130,2	218,8	231,1	93,4
F3	108,9	102,5	245,6	213,7	123,95
F4	86,21	91,74	403	398,7	311,875

Among the activated carbon variations, formula F4 (with 0.25 grams of activated carbon) was selected as the best formulation, based on Table 4.

Subsequently,cocamide DEA was added in varying amounts to evaluate its impact on pH and foam stability, as shown in Table 5.

Table 5. pH of Liquid Soap with the Addition of Cocamide DEA

Sample	Experiment 1	Experiment 2	average	SNI
F0	8,09	8,09	8,09	4-10
F5	9,18	9,06	9,12	
F6	9,21	9,16	9,19	
F7	9,33	9,24	9,29	

Cocamide DEA, a derivative of coconut oil, acts as a foam stabilizer and soap softener. Its basic properties contribute to the increase in pH while remaining within safe limits as defined by SNI. The addition of cocamide DEA also influenced foam stability, as presented in Table 6.

Table 6. Foam Stability Analysis of the Addition of Cocamide DEA

Sample	Experiment 1 (cm)			Foam Stability (%)
	Initial height	Final height	Δh	
F0	5,85	4,85	1	82,895
F5	5,55	4,6	0,95	82,807
F6	6,8	6,35	0,45	91,239
F7	7,9	7,3	0,6	89,230

As seen in Table 6, the addition of cocamide DEA enhances foam stability in liquid soap. However, a decrease in stability was observed in formula F7, possibly due to the hygroscopic nature of cocamide DEA and the formation of oversized foam bubbles, which cause the foam film to rupture easily. This finding aligns with Setyawan et al. (2009), who reported that excessive surfactant concentration may impair adsorption at the foam interface, leading to coarsening and coalescence phenomena.

The optimal formula from this test was F6, containing 0.25 grams of activated carbon, 2 grams of cocamide DEA, and 97 grams of other ingredients. This formulation produced a liquid soap with a pH of 9.185 and foam stability of 91.239%.

As a further development, orange peel extract was incorporated into the F6 formula to assess its impact on pH, foam stability, antimicrobial potential, and fragrance. According to the literature, tannins in orange peel extract exhibit antimicrobial activity against organisms such as E. coli, S. aureus, Saccharomyces cerevisiae, and Aspergillus niger. However, this study did not include total plate count testing.

Two formulations were tested: (1) orange peel extract : cocamide DEA : activated carbon : other ingredients = 1:2:0.25:97 and (2) 2:2:0.25:97. The results showed that pH increased to 9.715 (F8) and 9.78 (F9), due to the alkaline nature of the orange peel extract.

Foam stability also increased to 91.538% (F8) and 93.076% (F9). This improvement is likely due to the saponin content in the extract, which reduces surface tension and enhances interfacial attraction, thereby strengthening foam structure.

After testing the pH, soap effectiveness, and foam stability, the best formula was obtained in the manufacture of liquid soap with the addition of activated carbon, cocamide DEA, and orange peel extract. The best formula is 0.25 grams of activated carbon, 2 grams of cocamide DEA, 2 grams of orange peel extract, and a total of 97 grams of other raw materials. The liquid soap has a pH of 9.78 and foam stability of 93.076%.

Tabel 6. Free Alkaline Analysis

Titration volume (v)	Sample weight (w)	N HCL	Free alkali content (%)	SNI Free Alkali Content
0.5	5	0,1	0,06%	Max 0,5%

The free alkali test aims to measure the level of alkali in soap that does not react or is saponified with fatty acids. A high free alkali value can indicate that soap can irritate. Based on the test results of the HCl titration method, it was obtained that the free alkali for F9 was 0.0377%. When compared with SNI 2588:2017 (Table 2.1), the maximum free alkali is 0.1%, so the soap that has been made is according to standards. Too much alkali can make the emulsion in the solution split, causing an inhomogeneous solution, but the reaction time will be longer if a thinner alkali is used or the concentration of alkali is small (Levenspiel, 1972).

4. CONCLUSION

Based on research conducted, the optimal liquid soap formulation is the addition of 0,25 grams of activated carbon, 2 grams of cocamide DEA and 2 grams of orange peel extract. This formulation resulted in a pH value within the range of 8-9, foam Stability of 93,076%, and a free alkali content of 0.06%. Among all tested parameters, **formulation F9 demonstrated the best performance**. The combination of cocamide DEA, activated carbon, and orange peel extract provided a synergistic effect: high cleansing ability from activated carbon, stable foam from cocamide DEA and saponins, and a skin-safe pH and alkali level. This unique combination has not been widely documented in previous literature, highlighting the **novelty of the formulation approach** in optimizing liquid soap from waste materials.

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