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Formulation of Solid Soap Preparation from Used Cooking Oils with Pineapple Peel Eco-enzyme

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Abstract
This study explores the formulation and quality evaluation of solid soap made from recycled cooking oil enriched with fermented Ananas comosus (pineapple) peel extract. Three formulations were prepared using varying concentrations of pineapple peel eco-enzyme, while maintaining consistent proportions of palm sugar and water. The soap samples underwent physicochemical characterization in accordance with Indonesian National Standards (SNI). Results showed that all formulations had pH values within the acceptable range. Moisture content met regulatory limits in two formulations. All samples exhibited good foam stability, although the free fatty acid content exceeded permissible levels, likely due to extended hydrolysis during processing. Organoleptic assessment revealed uniform cream coloration, a characteristic aroma resembling soybean milk that decreased with higher eco-enzyme concentrations, and increased astringency corresponding to the concentration of pineapple extract. The soap maintained a solid texture with varying degrees of tackiness. This research demonstrates the potential for converting household waste into value-added products, while highlighting the need for further optimization to ensure compliance with commercial quality standards.

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INTRODUCTION

Cooking oil, as one of the most commonly used types of vegetable oil in food preparation particularly frying primarily consists of triglycerides (Fitri et al., 2019). Repeated use of cooking oil can lead to degradation through hydrolysis and oxidation, which is typically indicated by unpleasant odors and a progressively darker color (Prihanto & Irawan, 2018). When directly disposed of into the environment, used cooking oil becomes a pollutant to both water and soil (Mukhlison et al., 2021). Moreover, its consumption poses significant health risks. Therefore, it is essential to manage used cooking oil appropriately and, where possible, convert it into economically valuable products (Ariyani, 2020). Through a purification process, waste cooking oil can be recycled into raw materials for non-food industries, such as the production of bar soap (Widiani & Novitasari, 2023).

For centuries, soap production has been practiced, particularly for medicinal purposes in Europe. Solid soap is a common product encountered in daily life and is typically formulated using sodium hydroxide or caustic soda (NaOH) as the alkaline agent. One of the main advantages of solid soap is its glycerin content, which is beneficial for individuals with skin conditions such as eczema. In addition, it has low environmental impact and can serve as a natural exfoliant (Arlofa et al., 2021). Solid soap derived from used cooking oil generally has a pH ranging from 8 to 11, making it safe for skin application. Excessive alkalinity can cause skin irritation, while overly acidic formulations may result in skin dryness. Besides being dermatologically safe, soap should ideally possess antibacterial properties to effectively eliminate harmful microorganisms.

Eco-enzyme is a substance commonly utilized as an insecticidal, antifungal, cleansing, and antibacterial agent (Susanti & Juliantoro, 2021). It is a natural, multipurpose liquid derived from a fermentation process involving water, sugar, and organic kitchen waste such as fruit and vegetable residues (Viza, 2022). Eco-enzyme offers environmental benefits, low production costs, and ease of application (Husniah & Gunata, 2020). The natural alcohol content within eco-enzyme has been shown to effectively eliminate germs, viruses, and bacteria.

As an effective approach to waste management, eco-enzyme production allows for the reuse of household organic waste, particularly vegetable and fruit scraps. One such example is pineapple peel, which contains flavonoids, bromelain, tannins, phytates, and oxalates (Vama & Cherekar, 2020). Flavonoids are known to inhibit bacterial energy metabolism, while bromelain, a proteolytic enzyme, can suppress bacterial growth by breaking down bacterial protein bonds (Dabesor et al., 2017).

Eco-enzyme derived from pineapple peel has been proven to inhibit bacterial growth, particularly *Staphylococcus aureus* (Mubarokah & Halimatussa'diah, 2023). On the other hand, used cooking oil contains a high level of saturated fatty acids, making it a suitable raw material for soap production (Hanjarvelianti & Kurniasih, 2020). Soap is produced through the saponification process, in which triglycerides react with sodium hydroxide (NaOH) to yield soap, with glycerin as a by-product (Arlofa et al., 2021).

The addition of eco-enzymes derived from pineapple peel in the manufacture of solid soap from used cooking oil is a new breakthrough in the processing and utilization of used cooking oil. This approach is supported by research conducted by (Rachmadani et al., 2023), where eco-enzymes were added to the soap formulation. The results of the study showed that the addition of eco-enzymes increased the ability of soap to eliminate germs, viruses, and bacteria, while maintaining its suitability for use.

Based on the temperature applied, soap can be manufactured using the hot process, cold process, or the melt and pour method (Lugiana et al., 2022). The cold process typically requires a curing period of 2 to 4 weeks, whereas the hot process only takes about an hour (Fatimah et al., 2021). The cold process offers the advantage of preserving the integrity of oils used in the formulation, as it avoids excessive heat that may degrade their beneficial properties (Purnavita et al., 2021). Additionally, the cold process tends to produce a softer soap texture and is relatively simple to implement (Ohello, 2022).

Making solid soap with the addition of pineapple peel ecoenzymes is expected to provide a significant contribution in helping to overcome household waste problems. This research presents a novel approach byintegrating pinneaple peel ecoenzyme into solid soap made from used cooking oil an area that has received little attention highlight its potential for sustainable, value-added product development.

METHOD

Tools and Materials

The tools utilized in this study includes an eco-enzyme storage container, analytical balance, beaker glass, filter paper, glass funnel, graduated pipette, measuring cylinder, Erlenmeyer flask, volumetric flask, glass stirrer, overhead stirrer, electric stove, pycnometer, dropper pipette, pH meter, desiccator, oven, petri dish, burette, stand, clamp, sieve, soap mold, volumetric pipette, and watch glass. The materials employed consist of used cooking oil, 10% activated carbon, sodium hydroxide (NaOH), hydrochloric acid (HCl), 96% ethanol, 1% phenolphthalein indicator, potassium hydroxide (KOH), pineapple peel, palm sugar, and distilled water.

Making Eco-enzyme

The materials required for eco-enzyme production include pineapple peel, palm sugar, and clean water. The preparation steps begin with thoroughly washing the pineapple peel. The standard ratio used is 3:1:10 for fruit peel, palm sugar, and clean water, respectively. In this study, however, the proportion of fruit peel varied across the different experimental variables, as outlined in Table 1.

Table 1. Eco-enzyme Variable

Sample	Pineapple peel (gr)	Palm sugar (gr)	Clean water (mL)
F1	150	50	500
F2	300	100	1000
F3	450	150	1500

Used Cooking Oils Processing

Used Cooking Oils Filtering Process

Prepare 1 liter of used cooking oil to be refined, then put it into a 1000 mL beaker, filter the used cooking oil from impurities using Whatman filter paper no. 42.

Neutralization Process

Prepare 300 grams of filtered used cooking oil. Make a 15% NaOH solution by dissolving 15 grams of NaOH in 100 mL of distilled water. Next, the filtered used cooking oil is mixed with 15% NaOH with a composition of 300 grams of used cooking oil: 15 mL of NaOH heated to a temperature of 40ºC while stirring at a speed of 200 rpm using an overhead stirrer for 10 minutes. The heated used cooking oil is then filtered using Whatman filter paper No. 42.

Bleaching Process

100 grams of activated carbon is sieved using a 60 mesh sieve and then weighed as much as 30 grams. Furthermore, the neutralized used cooking oil is heated to a temperature of 70ºC. 30 grams of activated carbon is put into the used cooking oil and then heated while stirring at a temperature of 150ºC 200 rpm using an over head stirrer for 60 minutes. The bleaching results are then filtered using Whatman filter paper No. 42.

Making Solid Soap

A 40% NaOH solution was prepared by dissolving 100 grams of sodium hydroxide in 250 mL of distilled water. From this solution, 150 grams were taken and heated to a temperature of 55°C. The filtered used cooking oil, post-bleaching, was then heated and stirred at 60°C with a stirring speed of 200 rpm for 45 minutes. While the oil was being heated, the preheated 40% NaOH solution was gradually added.

The next step involved mixing the eco-enzyme with the oil and NaOH solution in a ratio of 1:2 (100 grams of the oil and NaOH mixture : 50 grams of eco-enzyme). Three samples were prepared, corresponding to the three eco-enzyme variable treatments. The final mixture was poured into molds and allowed to sit for 1–2 days until the soap solidified. After demolding, the soap bars were left to cure for 25 days to complete the drying process.

SNI Test for Solid Soap

pH Test

Prepare 600 mL of distilled water then boil it. 100 mL of boiled distilled water is put into each beaker glass containing 1 gram of soap sample F1, F2, and F3. Stir the soap until homogeneous then check the pH using a pH indicator.

Free Fatty Acid Content Test

Prepare 100 mL of 0.1 N standard potassium hydroxide (KOH) solution. A volume of 0.5 mL of phenolphthalein indicator is taken. Soap samples F1, F2, and F3 are each weighed to 0.01 grams and heated with 200 mL of 96% ethanol at 70°C until the soap is completely dissolved. When the solution approaches boiling, 0.5 mL of phenolphthalein is added to the soap-ethanol mixture. The heated mixture is then titrated with 0.1 N KOH standard solution until a persistent pink coloration is observed. The free fatty acid content is calculated using Equation 1.

$$Free\ Fatty\ Acid = \frac{282\ \times V \times N}{b} \times 100\% \qquad (1)$$

Description:
Free fatty acids in units of % mass fraction
V : KOH volume
N : KOH normality
B : test weight
282 : equivalent weight of oleic acid

Water Content Test

Soap samples F1, F2, and F3 were each weighed as much as 5.05 grams. The samples were heated in an oven at a temperature of 150ºC for 1 hour. The heated samples were then weighed. Heating in the oven was repeated until the sample weight was constant.

Foam Stability Test

The soap samples were weighed as much as 1 gram each. The soap samples were then put into a 20 mL test tube containing 10 mL of distilled water. The samples were shaken for 20 seconds. The foam formed was then measured for its height. Then let it stand for 5 minutes and then measure the height of the foam formed again. The calculation of foam stability by equation 2.

$$Foam\ Stability = \frac{final\ foam\ height}{initial\ foam\ height} \times 100\% \qquad (2)$$

Organoleptic Test

Organoleptic tests include assessment of color, aroma, astringency, and texture.

RESULTS AND DISCUSSION

Eco-enzyme Fermentation

The production of eco-enzyme requires a fermentation period of three months, after which the resulting eco-enzyme is ready to be used as an additive in solid soap formulation. During the initial phase of fermentation, the mixture emits a scent dominated by palm sugar dissolved in water, accompanied by a slight pungent aroma of pineapple peel. Following three months of fermentation, the eco-enzyme develops a characteristic acidic odor indicative of successful fermentation. This observation is in accordance with the study of eco-enzyme production conducted by Nazurahani et al., (2022) which showed a strong fermentation aroma.

Figure 1. Beginning of eco-enzyme fermentation

Figure 2. Eco-enzyme after 3 months of fermentation

Solid Soap Produced

Soap making begins with processing used cooking oil to be neutralized and bleached, then making soap that is added with eco-enzyme with a ratio of 2:1 (used cooking oil: eco-enzyme). The resulting solid soap has the same texture as solid soap in general. In addition, if held with dry hands, it will feel slippery than commercial soap.

Figure 3. Solid soap right after making

Figure 4. Solid soap after being left for 14 days

pH Test Results

pH testing is one of the quality requirements for solid soap, as pH value determines whether the solid soap is suitable for use or not (Yulia et al., 2024). pH values that are too high or too low can cause skin irritation (Susanti & Juliantoro, 2021).

The pH test results obtained values for each variable as follows: F1 was 9.85; F2 was 10.13; and F3 was 10.2. These values comply with the standard pH range for solid soap generally established by the National Standardization Agency (1996), which ranges from 8 to 11 (Ayu et al., 2022). The results of the study showed that F3 with 450 grams of pineapple skin caused the pH to increase to 10.2, which was higher when compared to the increase in pH in F1 (150 grams of pineapple skin) and pH in F2 (300 grams of pineapple skin).

This finding aligns with previously conducted research, which explained that research results showed the sample with 5% pineapple core extract concentration caused the pH to increase to 9.6, higher compared to the pH increase in samples with 3% pineapple core extract concentration and F2 with 4% pineapple core extract concentration (Octora et al., 2020). However, in another study conducted by (Chairul et al., 2025), the pH of solid soap in the same treatment according to SNI standards ranged from 9.44-10.41.

Pineapple fruit itself contains various types of organic acids, resulting in a relatively low pH from the pineapple. The pH increase, when averaged, has a pH value of 10, indicating no significant increase between variables. This is because of 40% NaOH, which is one of the main components in soap stock production, having a high pH of 13, classified as a strong base, thereby dominating the pH of the formed soap (Ayu et al., 2022).

Free Fatty Acid Content Test Results

Fatty acid measurement was also conducted to determine the number of fatty acids present in the soap. High levels of free fatty acids can cause a decrease in the quality of solid soap preparations. According to SNI (2016), the free fatty acid content in solid soap must not exceed 2.5%. In a study conducted by (Chairul et al., 2025), the level of free fatty acids was found to range from 0.23 - 0.70% according to SNI standards.

In this study, the results of free fatty acid content were too high and did not meet SNI (2016) standards. This occurred due to an excessively long hydrolysis process, which caused fatty acid levels to increase (Susanti & Juliantoro, 2021). Therefore, the three samples with their respective variables consisting of F1 = 56.4%; F2 = 56.4%; and F3 = 28.2% did not meet the requirements for free fatty acid content according to SNI (2016). In addition, high free fatty acids are caused by the saponification reaction not occurring perfectly, causing the soap to smell rancid and reducing the binding power of the soap to sweat, fat and oil dirt (Jalaluddin et al., 2018).

Water Content Test Results

Water content represents the amount of water present in a material expressed as a percentage. Soap hardness is also influenced by water content. Higher water content results in softer soap consistency, while lower water content leads to harder soap texture (Susanti & Juliantoro, 2021). The composition of each eco-enzyme variable utilized affects the water content present in each soap variable. The water content results for each variable were as follows: F1 = 15.48%; F2 = 13.08%; and F3 = 13.03%. Based on these variables, there was a reduction in the percentage of water content in the soap. This was caused by the reduced amount of water used in the soap formulation that coincided with the increased addition of pineapple peel eco-enzyme (Ayu et al., 2022).

Furthermore, the water content value in sample F1 did not meet SNI (2016) standards, as the water content value exceeded 15%. This was due to the addition of materials with hygroscopic properties that absorb moisture from the air, such as glycerin, resulting in water content exceeding the standards established by SNI for solid bath soap (Yulia et al., 2024). In contrast to variables F2 and F3, whose water content test values were compliant with SNI (2016) as they were below 15%. High water content in soap can affect the characteristics of the soap in use and storage. Soap that contains a lot of water makes the soap mass shrink easily and the soap is not hard (Sa'diyah et al., 2018; Surilayani et al., 2019).

Foam Stability Test Results

Foam is a colloidal system where the dispersed phase is gas and the dispersing medium is liquid. Foaming agents work to maintain bubbles within thin layers, with gas molecules dispersed in the mixture (Susanti & Juliantoro, 2021).

Based on the foam stability test results obtained, the foam stability values were: F1 = 90.69%, F2 = 89.74%, and F3 = 83.33%. Other research also indicated that foam stability ranges from 93.57% to 94.91%, with commercial soap foam stability at 94.50% (Rizka, 2017). The foam stability of solid soap made from pineapple peel eco-enzyme demonstrates sufficiently good foam stability. High foam formation during the saponification process occurs due to the complete saponification reaction between fatty acids and base (Susanti & Juliantoro, 2021).

Organoleptic Test

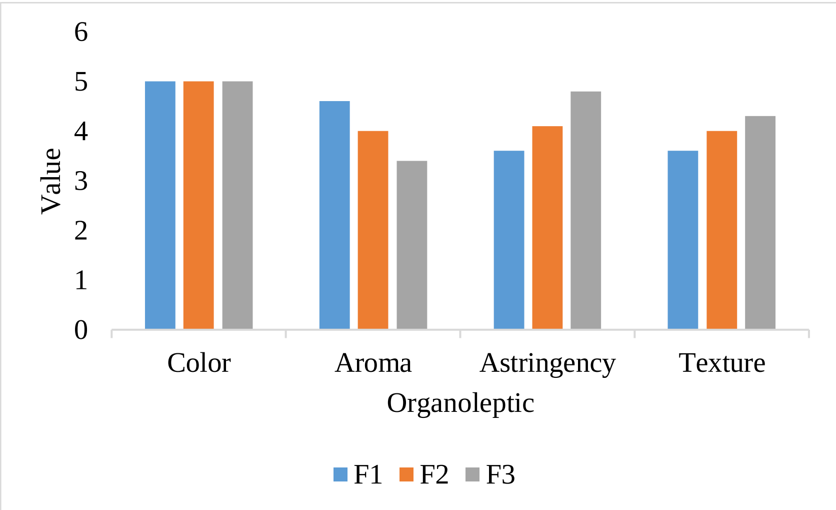

Figure 5. Organoleptic test results for each variable

Organoleptic testing is a test based on sensory processes by observing the texture, color, and odor of soap preparations during four testing periods to determine changes in the physical form of the soap during storage (Hilmarni et al., 2024). The test results showed that variables F1, F2, and F3 tend to have similarities among them. In terms of odor, the soap emits a soybean milk-like aroma.

This occurred due to the mixture of used cooking oil odor with pineapple peel odor. Additionally, in terms of color, variables F1 through F3 all produced cream-colored soap. This occurred because tannins undergoing extraction are natural polar colorants that produce colors ranging from yellow to dark brown. The combination of various compounds in pineapple peel produces brown eco-enzyme that forms a brownish-yellow or cream color when mixed with other ingredients typically used in soap production, which are generally white.

In terms of texture, the soap produced from variables F1 through F3 has a solid texture. This occurred because the amount of water affects the hardness of the formed soap. High water content makes soap more water-soluble and therefore softer. In terms of astringency, variable F1 has low astringency (slippery), while variable F3 has high astringency. This is because the quantity of materials in variable F3 is greater compared to variables F1 and F2 (Ayu et al., 2022).

CONCLUSION

The study successfully produced solid soap from used cooking oil supplemented with pineapple peel eco-enzyme across three formulations with varying concentrations. While pH values (9.85-10.2) and foam stability (83.33-90.69%) met acceptable quality standards, free fatty acid content significantly exceeded the SNI maximum limit of 2.5%. Only formulations F2 and F3 achieved compliant water content values (<15%). Organoleptic properties were consistent across formulations in terms of color, though astringency increased proportionally with pineapple peel concentration. These findings suggest that while the concept of utilizing waste materials for soap production is promising from an environmental perspective. This research demonstrates potential for converting household waste into value-added products while establishing a foundation for future optimization studies. Aspects that require improvement include reducing free fatty acid levels through better control of the hydrolysis process, and optimizing water content in all formulations as well as further testing of the effectiveness of the effect of ecoenzymes on bacteria.

RECOMMENDATIONS

Further research is expected to optimize eco-enzyme preparations based on their variables, evaluate dermatological safety parameters, assess the antibacterial properties of soap formulations against common dermatological pathogens to quantify the contribution of pineapple peel eco-enzyme to antimicrobial activity, and investigate in greater depth the underlying factors responsible for the current formulation's non-compliance with solid soap suitability standards.

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