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## The Use of Palm Oil Final Effluent as Solid Soap to Support a Sustainable Economy

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### Abstract

The palm oil industry plays a vital role in Indonesia's economy, but it also poses serious challenges due to the waste it generates. Much of this waste remains underutilized, with current efforts primarily focused on pollution control rather than generating significant economic benefits. Final effluent, as the end-of-process waste, still has the potential to be reused because it contains residual oil. This study aims to explore the utilization of final effluent as an additive in the production of bar soap, evaluate the product's quality characteristics, and assess its potential in supporting the circular economy and increasing the industry's value added. The study employed a laboratory experimental method using a quantitative-descriptive and comparative approach. Residual oil was extracted using an organic solvent, purified, and then formulated into solid soap via the hot process method. Evaluation was based on physical and chemical parameters. The results showed that the soap met SNI 3532:2021 standards for pH and moisture content, excelled in foam height, but free alkali still required adjustment through NaOH control. This utilization has the potential to increase the economic value of waste.

### Keywords

Circular Economy, Final Effluent, Residual Oil, Solid Soap.

## 1. Introduction

Indonesia currently ranks first as the world's largest palm oil producer, accounting for approximately 59% of global production. It is followed by Malaysia at 24%, and other countries, including Ghana, which accounts for about 17% (National Research and Innovation Agency, 2024). As the world's largest palm oil producer, Indonesia holds a strategic position to maximize the utilization of its natural resources while strengthening the implementation of sustainable management. From a macroeconomic perspective, the palm oil commodity plays a crucial role as it is not only one of the primary foreign exchange earners but also significantly contributes to community economic growth and job creation (Ronaully, 2024). Unfortunately, despite yielding high economic benefits, palm oil cultivation still has the potential to cause serious environmental issues due to the waste it generates. Waste is the byproduct generated from a production process, whether industrial or domestic (household), commonly known as trash, whose presence under certain conditions is undesirable to the environment because it lacks economic value (Faizah et al., 2022).

Every year, the oil palm industry generates a massive volume of biomass, ranging from empty fruit bunches, plant trunks, liquid waste, to palm kernel shells. Much of this residual material is still simply discarded without adequate utilization, particularly liquid waste (Coordinating Ministry of the Economy of the Republic of Indonesia, 2024). Palm oil mill effluent is an agro-industrial organic waste generated during the processing of fresh oil palm fruit bunches. This effluent contains water, oil residues, and organic solids formed as byproducts of the Crude Palm Oil (CPO) production process (Kurniawan et al., 2022).

The significant volume of waste generated has spurred various management efforts that focus not only on pollution control but also on increasing value-added benefits. Numerous palm oil waste treatment solutions have been extensively researched and developed, ranging from biological treatments such as biogas and the use of organic fertilizers to filtration systems and chemical neutralization. Some solutions, such as biogas, do offer economic value-added through energy savings, additional income, and the creation of local jobs (Nugroho et al., 2025). However, other solutions, such as organic fertilization or chemical filtration, remain more focused on pollution control without providing significant economic contributions. This situation presents an opportunity to introduce solutions that not only address environmental issues but also generate new economic benefits through the productive utilization of waste.

The challenge is whether a solution can be found that not only mitigates pollution potential but also generates added value from the palm oil waste itself. This series of questions opens opportunities for the emergence of critical and innovative ideas, particularly from the younger generation, to formulate more creative, sustainable approaches. This study aims to explore alternative uses of palm oil waste focused on increasing added value, evaluate the potential for developing it into functional products with economic value, and examine its contribution to supporting the implementation of a circular economy and sustainable economic development. One of the innovations developed is the use of final effluent as an additive in the formulation of bar soap.

## 2. Literature Review

### 2.1. Palm Oil Waste and Its Utilization Potential

The palm oil industry generates various types of waste, both solid and liquid, that have the potential for reuse. Palm Oil Mill Effluent (POME) is one of the primary types of waste produced in large quantities during the Crude Palm Oil (CPO)

production process. This effluent contains water, organic matter, and residual oil that still hold value if properly treated (Kurniawan et al., 2022). To date, the management of liquid waste has primarily focused on pollution control efforts through biological, chemical, and physical methods, such as anaerobic ponds, filtration, and neutralization.

Several studies indicate that palm oil waste can be utilized to produce value-added products, such as biogas and organic fertilizer. Utilization as biogas is considered capable of providing economic benefits through energy efficiency and opportunities for additional income (Nugroho et al., 2025). However, not all waste treatment methods contribute significantly to the economy. Many approaches remain focused on reducing environmental impacts without optimizing their economic potential.

In the context of the circular economy, waste is no longer viewed as a byproduct but as a resource that can be reused within the production cycle. This concept drives innovation in transforming waste into new products with both utility and market value. Therefore, the utilization of liquid waste, particularly final effluent still containing residual oil, presents a strategic opportunity to develop as an alternative raw material for other industries, such as personal care products. Research has demonstrated the technical feasibility of this approach. Purba et al. (2023) successfully formulated transparent solid soap from purified coconut oil industrial liquid waste, while Monteiro et al. (2025) highlighted how waste from the hair care industry can be cycled back into the production chain, reinforcing the viability of a circular model in the beauty and personal care sector.

### ***2.2. The Use of Waste Oil in the Production of Bar Soap***

Bar soap is a product resulting from the saponification reaction between fatty acids and a strong base, such as sodium hydroxide (NaOH), and is widely used in daily life. The quality of the soap is influenced by the type and composition of the oil used, as well as the manufacturing process. The hot process method is a soap-making technique performed at high temperatures to accelerate the saponification reaction and produce soap that is ready for use more quickly. Vegetable oils, including palm oil, contain fatty acids suitable for soap making because they produce good lather and possess effective cleansing properties. In several studies, recycled oils or waste oils that still contain fatty acids have also been utilized as alternative raw materials in soap production, while ensuring proper purification processes to enhance their quality (Arita et al., 2020).

Quality parameters for bar soap generally adhere to established standards, such as SNI 3532:2021, which include pH, moisture content, foam stability, and free alkali content (Anggraini et al., 2023). Evaluating these parameters is crucial to ensuring the safety and quality of the final product. The use of residual oil from final effluent as an additive in soap formulations is an innovation with the potential to increase the value of waste while producing functional products. Kharisma & Yerizam (2025) successfully formulated solid soap using purified residual oil extracted from palm oil final effluent. Their evaluation based on SNI 3532:2021 showed that parameters such as pH (9.8-10.2), moisture content (max 15%), and foam stability met the required standards, although the free alkali content (0.22-0.28%) exceeded the SNI maximum limit of 0.1%, indicating a need for process optimization. Through a combination of experimental and comparative approaches in this study, a comparison between soap made from pure oil and a mixture of residual oil can provide insight into the feasibility of using waste as an alternative raw material. This also supports the development of products based on the principles of sustainability and the circular economy within the palm oil industry, where integrated biorefinery approaches are increasingly recognized as key strategies for converting waste streams into valuable products.

### 3. Methods

This study employed a laboratory experimental method using a quantitative-descriptive and comparative approach, conducted at the Chemical Engineering Laboratory of Sriwijaya State Polytechnic. The study aimed to evaluate the physical characteristics and chemical quality of solid soap made from oil derived from the purification of palm oil final effluent. The quantitative approach was used to measure soap quality parameters, including organoleptic testing, pH, moisture content, foam height and stability, and free alkali content. Meanwhile, the descriptive approach was used to describe the physical properties of the soap and the results of observations during the process from oil extraction to soap production. A comparative approach was used to compare two soap formulations: 100% palm oil soap and a blended soap consisting of 90% palm oil and 10% oil from the final effluent purification process, in accordance with SNI 3532:2021.

The extraction process was conducted using the organic solvent n-hexane at a 1:1 (v/v) ratio, followed by evaporation to separate the solvent, yielding crude oil. The oil was then frozen at  $-22\text{ }^{\circ}\text{C}$ , reheated, and filtered to obtain solvent-free oil. This step produced a purified raw material ready for use. The purified oil was used in the production of solid soap via the hot process method at  $60\text{--}70\text{ }^{\circ}\text{C}$  using two different formulations. Primary data was obtained through laboratory experiments, including organoleptic testing using the five senses, pH measurement with a pH meter, moisture content determination using thermogravimetry, foam height testing via the shake test, and free alkali content determination through titrimetry.

Secondary data was obtained through literature reviews, specifically the SNI 3532:2021 standard, as well as relevant journals and scientific sources as references for methods and result comparisons. Economic analysis was conducted qualitatively, focusing on potential value-added, waste management efficiency, and opportunities for developing derivative products. The soap was made using NaOH as a saponification catalyst; the same dyes and fragrances were added, and the mixture was stirred until trace was reached, then molded and cured for four weeks. Quality evaluation was performed based on the parameters specified in SNI 3532:2021.

### 4. Results

This study produced data on the use of oil derived from the final purification of palm oil effluent as an additive in the production of bar soap. The research results include the oil extraction and purification process, soap formulation, and evaluation of physical characteristics and chemical quality based on SNI 3532:2021 standards. The extraction process was carried out using the organic solvent n-hexane at a 1:1 (v/v) ratio, followed by evaporation to separate the solvent from the oil. This stage produced crude oil that still contained impurities; therefore, a solidification process at  $-22\text{ }^{\circ}\text{C}$ , reheating, and filtration were performed to obtain purer oil. This process aligns with previous research stating that extraction using organic solvents is effective for recovering residual oil from palm oil mill effluent (Arita et al., 2020; Chang, 2020).

The final effluent used in this study was found to still contain residual oil. Based on laboratory test results, the oil and grease content reached  $801.4\text{ mg/L}$ . Although relatively low, oil accumulation on an industrial scale is significant, potentially reaching 1.5–2 tons per day at a plant with a capacity of 400 tons of fresh fruit bunches (FFB) per day (Hariyadi & Jelita, 2024). The presence of this residual oil presents an opportunity for further utilization, allowing previously unused waste to be processed as an additive in the development of solid soap formulations. The physical characteristics of the oil obtained from the final purification of the final effluent are shown in Table 1.

**Table 1.** Physical Characteristics of the Oil Obtained from Final Purification

No	Parameter	Observation Result
1	Color	Bright Golden Yellow
2	Clarity	Clear
3	Viscosity Level	Stable Liquid
4	Smell	Does Not Smell Like Solvent
5	Solvent Content	Very Low - Lost
6	Homogeneity	Stable
7	FFA (%)	Not Tested
8	Suitability As Raw Material	Worth Using

The purified oil was then used to produce bar soap using the hot process method at a temperature of 60–70 °C. This study employed two formulations: a control soap made from 100% palm oil and an innovative soap made from a blend of 90% palm oil and 10% oil purified from final effluent. Both formulations used NaOH as the saponification catalyst, along with the same additives: colorants and fragrances. The manufacturing process was carried out until the trace stage was reached, after which the soap was molded and underwent a curing period of four weeks. The results of the organoleptic test showed that the innovative soap had physical characteristics not significantly different from those of the control soap.

The soap has a solid form, a fairly hard texture, and an aroma consistent with the fragrance used. This indicates that the addition of oil from the final effluent does not significantly negatively impact the soap’s physical properties. Moisture content testing showed that both formulations met the SNI 3532:2021 standard, i.e., not exceeding the maximum limit of 23%. An appropriate moisture content indicates that the soap has good stability and does not soften easily during storage (Darmawan & Arifin, 2020). Additionally, low moisture content also affects the product’s shelf life. The results of the soap production after a curing period of 1 week can be observed in Figure 1.



**Figure 1.** Soap Production After a Curing Period of 1 Week

Description:

- (a) Control Soap with a 1-week curing period,
- (b) Formula 1 and 2 Solid Soap,
- (c) Innovative Soap with a 1-week curing period

This consistency indicates that the soap has a stable texture, does not soften easily during storage, and is able to maintain its hardness. From a safety perspective, the pH value of the innovative soap falls within the permissible range according to SNI standards, making it safe for use on the skin. This indicates that the saponification process proceeded properly and did not result in a product that is either too acidic

or too alkaline. The suitability of the pH value serves as a key indicator in determining the safety of soap as a personal care product.

Foam height and stability testing indicate that the innovative soap performs better than the control soap. The foam height produced is higher and relatively stable, indicating good cleaning ability. This aligns with the characteristics of palm oil, which can produce sufficient foam during the saponification process (Kurniawan et al., 2022). However, the results of free alkali content testing indicate that the innovative soap has not yet fully met the established standards. High free alkali content may be caused by inaccuracies in the amount of NaOH in the formulation. This condition suggests that adjustments to the ingredient composition, particularly regarding the use of bases, are necessary to produce soap of higher quality.

From an economic perspective, the research findings indicate that the utilization of final effluent holds potential for enhancing the value of industrial waste. Waste that was previously unused can be processed into functional products with market value. This aligns with the circular economy concept, which emphasizes the reuse of resources within the production cycle (Hadi et al., 2025). The high potential for foam formation and the ability to transform waste into valuable materials make the use of final effluent oil as a raw material for solid soap capable of supporting the implementation of a circular economy while producing functional and sustainable products. The results of the physical and chemical quality tests of the solid soap are presented in Table 2 and Table 3.

**Table 2.** Organoleptic Test Results of Solid Soap

Formulation	Indicator		
	Color	Texture	Form
Formula 1: Control Soap	Pink	Hard	Solid, conforms to the mold
Formula 2: Innovation Soap	Orange	Hard	Solid, conforms to the mold

**Table 3.** Results of Physical and Chemical Quality Tests on Bar Soap

Sample Name	Analysis Results				
	Water Content (%)	High Foam (Cm)	Foam Stability (%)	pH	Free Alkali
Formula 1: Control Soap	11.38	8.6	87.20	10	0.17
Formula 2: Innovation Soap	13.70	9.5	68.42	10	0.21

In addition, the utilization of residual oil from final effluent has the potential to reduce waste management costs, which have long been an operational burden for the industry. By converting some of the waste into raw materials, the industry can improve efficiency while reducing its environmental impact (Nugroho et al., 2025). The results of this study also indicate opportunities for the development of waste-based soap products on a larger scale, including within the small and medium-sized enterprise (SME) sector. Soap products made from residual oil can be developed as environmentally friendly products that possess market value and competitiveness. Thus, the results of this study demonstrate that the utilization of final effluent as an additive in the production of bar soap is not only technically feasible but also holds significant economic and environmental potential.

## 5. Discussion

The results of this study indicate that the use of final effluent as an additive in the production of bar soap is an innovation with great potential for supporting circular economy-based waste management. The presence of residual oil in final effluent is

the primary factor enabling this waste to be reused as an alternative raw material. Although the oil content is relatively small, it still holds value if processed using the appropriate methods (Saukani et al., 2025). This demonstrates that industrial liquid waste need not always be viewed as waste but rather as a potential resource that can still be utilized.

From a technical perspective, the oil extraction and purification process using organic solvents has proven effective in producing oil suitable for solid soap formulations. The use of n-hexane as a solvent successfully separates the residual oil from the liquid phase, which is then purified through subsequent stages such as evaporation, freezing, and filtration. These results align with previous research stating that solvent extraction methods can enhance the utilization of residual oil from palm oil mill effluent (Arita et al., 2020). The success of this process reinforces the idea that simple laboratory-based technologies can serve as a first step toward optimizing the utilization of industrial waste.

Soap quality test results indicate that most parameters meet the SNI 3532:2021 standard, particularly regarding pH and moisture content. This compliance indicates that the produced soap is safe for use and possesses adequate quality as a personal care product. Additionally, the innovative soap demonstrates superior performance in terms of high foam yield and stability. The higher and more stable foam indicates better cleaning ability, which is one of the indicators of soap quality (Darmawan & Arifin, 2020). This also suggests that the addition of oil derived from the purification of final effluent does not reduce the soap's performance; in fact, it has the potential to enhance its quality.

However, the free alkali content remains a challenge that requires attention. Research results show that the free alkali content in the innovative soap does not yet fully meet established standards. This indicates that the NaOH formulation in the saponification process is not yet optimal and requires further adjustment. High free alkali content can impact the safety of soap use, particularly as it may cause skin irritation. Therefore, formulation optimization is a crucial step in further product development.

From an economic perspective, the utilization of final effluent demonstrates significant potential for enhancing the value of industrial waste. This approach aligns with the circular economy concept, which emphasizes resource efficiency and waste reduction through the reuse of materials that still hold utility value (Hadi et al., 2025). By transforming waste into marketable products, industries can not only reduce the burden of waste management but also create new economic opportunities. This signifies a paradigm shift from viewing waste as a cost center to a value generator.

Furthermore, this innovation also opens opportunities for SME-based business development, particularly in the production of eco-friendly soap. Soap products made from waste-based raw materials hold a unique appeal in the market due to their sustainability and eco-friendly concepts. With relatively stable market demand, these products have the potential to contribute to community economic growth and the creation of new jobs (Nugroho et al., 2025). The results of this study indicate that the utilization of final effluent is not only relevant in the context of environmental pollution control but also holds strategic value in the development of sustainable products. Integrating this innovation into industrial systems has the potential to strengthen the implementation of the circular economy, improve waste management efficiency, and support more sustainable economic development.

## **6. Conclusion**

The use of final effluent oil in the production of bar soap demonstrates that waste can be part of the solution when managed properly. Amid growing demands for economic efficiency and resource optimization, this initiative shows that the younger

generation is capable of contributing through the development of circular economy-based solutions that are both practical and impactful. The utilization of final effluent has proven not only to add value but also to hold potential for development as a functional product with economic value, while supporting the strengthening of a sustainable circular economy. Economically, the innovation of utilizing final effluent as a raw material for solid soap offers benefits at multiple levels. At the industrial scale, this approach has the potential to reduce waste management costs and enhance resource utilization efficiency.

At the medium scale, the use of waste as an alternative raw material opens opportunities for developing value-added derivative products. At the micro level, this innovation has the potential to be developed by SMEs as an environmentally friendly product with market value, thereby supporting job creation and the strengthening of the local economy. The utilization of final effluent is not only technically and environmentally relevant but also has tangible economic implications. Moving forward, development efforts can focus on optimizing the formulation of soap based on final effluent oil, as well as fostering collaboration between educational institutions and the rapeseed oil industry.

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