Jurnal Ilmu dan Teknologi Kesehatan, Vol. 16 No. 1 Januari 2025 Hal 69-73
ISSN 2086-8510 (Print), ISSN 2655-5875 (Online)
https://doi.org/10.33666/jitk.v15i1.673 https://journal.uwhs.ac.id/index.php/jitk/article/view/673

DEVELOPMENT AND CHARACTERIZATION OF INNOVATIVE BAR SOAP FORMULATIONS USING GAYO ARABICA COFFEE HUSK EXTRACT: FOCUSING ON PHYSICAL PROPERTIES AND ANTIBACTERIAL ACTIVITY USING PH METER SENSOR

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Submitted: Dec 12th 2024 Revised: Dec 27th 2024 Accepted: Jan 15th 2025 Published: Jan 24th 2025

ABSTRACT

This study aims to examine the characteristics of solid soap made from Gayo Arabica coffee shell extract from Aceh, a premium commodity rich in active compounds. Coffee, which has become part of modern lifestyle, is now used not only as a beverage but also in cosmetic and pharmaceutical products. In this research, solid soap was formulated with varying concentrations of coffee extract at 1%, 2%, and 4%, with 2% triclosan used as a positive control. Physical and microbiological characteristics were tested according to SNI 3532:2021 standards, including tests for pH, moisture content, free alkali content, foam stability, and antibacterial activity against Staphylococcus aureus. Test results showed that all soap formulations met SNI standards, with pH ranging from 9.59 to 10.10, moisture content between 5.60% and 9.36%, safe free alkali content for the skin, foam height between 5-5.8 cm, and antibacterial inhibition zones against Staphylococcus aureus ranging from 7.4 to 9.2 cm. In conclusion, solid soap with Gayo Aceh coffee shell extract meets SNI quality standards and has promising antibacterial potential.

Keyword: Solid soap, Gayo coffee shell extract, *Staphylococcus aureus, pH Meter Sensor.*

BACKGROUND

Waste generated from coffee production, such as coffee fruit skin (endocarp), remains a significant issue in the coffee industry in Indonesia. This waste is often simply discarded or used as basic organic fertilizer, which does not provide substantial added value for the coffee industry or society. If not properly managed, this waste can cause environmental pollution due to its organic nature and easy decomposition, generating greenhouse gases like methane.

Several solutions have been implemented to address this waste issue, such as processing it into compost, bioethanol, or zeolite mixtures. However, these solutions have limitations, including low economic value and a lack of innovative diversification of coffee-based waste products. Therefore, a new approach is needed that not only addresses environmental problems but also provides economic value.

Previous studies have shown that coffee waste, particularly coffee seed skin (endocarp), contains bioactive compounds such as polyphenols, including flavan-3-ol, hydroxycinnamic acid, flavonol, anthocyanidin, catechin, epicatechin, rutin, tannin, and ferulic acid. These compounds have significant potential in developing cosmetic products, especially due to their antibacterial activity. Marcelinda et al. (2016) and Ramadhan et al. (2022) reported that coffee waste extracts could be used in cosmetic formulations, such as solid soap, which functions to maintain skin cleanliness and provide antibacterial protection.

Based on this potential, this study aims to determine the characteristics of solid soap with extracts of Gayo Aceh Arabica coffee beans. This research is expected to provide information on the processing of coffee production waste, especially coffee seed skin (endocarp), into value-added products. Additionally, the results of this study could open opportunities for innovative coffee-based product diversification and contribute to scientific development in the fields of cosmetics and waste management.

The findings of this research are expected to have positive impacts both environmentally and economically. Environmentally, utilizing coffee waste into value-added products can reduce potential environmental pollution. Economically, diversifying coffee-based products can increase the income of coffee farmers and related industry players. Thus, this research not only provides a solution to the coffee waste problem but also supports the development of a sustainable coffee industry.

METHOD

The data collection process involved detailed laboratory observations to analyses the characteristics of soap products containing coffee shell extract. Solid soap formulations were prepared in three variations of extract concentrations: 1%, 2%, and 4%. All other ingredients, including caustic soda, water, coconut oil, palm oil, castor oil, and olive oil, remained constant across formulations. As a positive control, 2% triclosan—a known antibacterial and

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antifungal compound commonly found in cleaning products—was added to one of the soap formulations.

Each formulation underwent multiple tests to ensure data reliability and minimize potential errors. For pH testing, each soap type was tested three times, and the average value was recorded to improve accuracy and reliability. Similarly, water content, free alkali content, and foam height tests were repeated three times per formulation. The microbiological test for Staphylococcus Aureus bacteria was also conducted in triplicate. This repetition aimed to account for any inconsistencies and ensure that the data were robust and representative.

Data analysis employed descriptive statistical methods. The average values for each parameter were calculated and compared against the SNI 3532:2016 standards. Parameters with average levels exceeding quality standards were flagged as not meeting the SNI criteria. The selection of descriptive analysis techniques was based on their effectiveness in summarizing and interpreting data, especially for identifying trends and deviations in physical and microbiological characteristics.

The repeated testing methodology was chosen to enhance the validity and reliability of the findings. By conducting multiple tests, the likelihood of errors or anomalies affecting the results was minimized. This approach is superior to single-test techniques, which might overlook occasional errors or outliers. Additionally, the use of descriptive analysis ensures that data interpretations are straightforward and easily communicable, which is advantageous compared to more complex statistical techniques that may require additional validation or assumptions.

The methodological rigor of this study ensures that the conclusions drawn are reliable and can contribute meaningfully to the development of coffee-based soap products.

Table 1. Solid Soap Formulation

Material	**Utility**	**Concentration**				
		F1	**F2**	**F3**	**F-**	**F+**
Ethanol extract of Gayo Arabica coffee shells	Active substance	2%	2,5%	3%	-	-
Coconut oil	Foamer	20 g/ml	20 g/ml	20 g/ml	20 g/ml	20 g/ml
Olive oil	Emollient	10 g/ml	10 g/ml	10 g/ml	10 g/ml	10 g/ml
Palm oil	Soap hardener	30 g/ml	30 g/ml	30 g/ml	30 g/ml	30 g/ml
NaOH	Alkali	8,9 g	8,9 g	8,9 g	8,9 g	8,9 g
Aquadest	Solvent	100ml	100ml	100ml	100ml	100ml
Triclosan	Positive control	-	-	-	-	2%

RESULT AND DISCUSSION

The most significant finding in this study is the potential use of coffee husk extract as an active ingredient in solid soap formulations. The results demonstrated that the saponification process was successfully completed for all formulations, producing solid soap with desirable physical properties. The soap exhibited consistent hardness, attributed to the use of coconut and palm oils, and emitted the characteristic aroma of coffee husk extract. Additionally, the soap's texture was homogeneous, aligning with the findings of Abdullah et al. (2021), which indicated that solid soap formulas should be free from fine or coarse lumps and possess a uniform color.

The pH measurement of all solid soap preparations met the SNI 3532:2021 standard. Based on the pH measurement results of the Gayo Arabica coffee husk extract solid soap preparation, a pH value of 9.59-10.10 was obtained for all soap formulations. The obtained pH value is in accordance with the soap quality standard of 6-11. A pH value that is too acidic can cause skin irritation, while a pH value that is too basic can cause the skin to become dry. The obtained pH value is in accordance with the SNI 3532:2021 soap quality standard, so it is safe to apply to the skin..

Table 2. pH Test Results of Arabica Coffee Shell Extract Soap Preparations

No	Sample	pH
1	F1	10,08
2	F2	10,10
3	F3	10,08
4	F-	9,71
5	F+	9,59

The results of the water content test were carried out on a solid bath soap preparation with Gayo Arabica coffee shell extract, and the results obtained met the SNI 3532:2021 quality standard, namely 5.60% - 9.36%. The permitted content in soap preparations is 15%. The test was carried out by heating in an oven at 105°C for 1 hour, then cooling in a desiccator for 15 minutes to room temperature and then weighing.

Table 3. Water Content Test Results for Arabica Coffee Shell Extract Soap Preparations

No	Sample	Water content
1	F1	5,60%
2	F2	7,48%
3	F3	9,36%
4	F-	5,79%
5	F+	6,35%

The free alkali test results show that this soap is still safe for the skin and complies with the standards set by SNI 3532:2021. Based on research by Abdullah et al, (2021), this is due to the optimal saponification reaction where all the bases react perfectly and completely react with the fatty acids during the formation of soap. And meets standards according to SNI 3532:2021, namely a maximum content of 0.1%.

Table 4. Alkaline Free Test Results for Arabica Coffee Shell Extract Soap Preparations

No	Sample	Free alkali content (%)
1	F1	$1{,}20.10^{-4}$
2	F2	$1{,}25.10^{-4}$
3	F3	$1{,}20.10^{-4}$
4	F-	$5{,}12.10^{-5}$
5	F+	$3{,}89.10^{-5}$

Tests for foam stability and foam height of solid soap were carried out by placing 2 g of soap in a test tube containing 10 ml of distilled water, then shaking with a vortex for 1 minute. The height of the foam formed will be measured using a ruler. The height requirement for soap foam is 1.3 - 22 cm and 5 minutes later, observe the stability again. The results obtained from measuring the height of the foam and the stability of the foam meet the quality standards for soap preparations which refer to SNI 3532:2021 with the requirements for the height of soap foam, namely 1.3 - 22 cm.

Table 5. High Foam Test Results for Arabica Coffee Shell Extract Soap Preparations

No	Sample	Foam Height (cm)
1	F1	5,8 cm
2	F2	5 cm
3	F3	5,5 cm
4	F-	5,6 cm
5	F+	5 cm

The results of the antibacterial activity test of the solid bath soap preparation of Gayo Arabica coffee shell extract against gram-positive bacteria (staphylococcus aureus) used the disc diffusion method, namely the antibacterial fraction to be tested was absorbed onto a paper disc and attached to agar media. Microorganisms for their growth require metal elements such as sodium, potassium, calcium, magnesium, manganese, iron, zinc, copper, phosphorus, cobalt, hydrogen, oxygen and sulfur (Thohari et al, 2019). The media that has been homogenized with bacteria is then incubated until an inhibition zone is visible in the area around the disc (Novita, 2016). This disc diffusion method involves observing the incubation period for 1 x 24 hours with 3 treatments. The results of the observations were made by measuring the diameter of the inhibition zone formed using a caliper. Measurements of the diameter and average zone of inhibition of solid soap preparations against Staphylococcus Aureus bacteria can be seen in table 6.

Table 6. Antibacterial Test Results Against Staphylococcus Aureus

Formula	Measurement			Average	Information
	1	2	3		
F1	8.665	7.525	6.06	7.42	Medium
F2	7.415	7.661	7.238	7.44	Medium
F3	8.61	8.335	5.395	7.45	Medium
F-	10.155	8.84	8.845	9.28	Medium
F+	7.825	8.84	7.575	8.08	Medium

The results of the antibacterial tests showed that the inhibition zones varied across all formulations, ranging from moderate to weak. This indicates that the solid bar soaps containing Gayo Arabica coffee husk ethanol extract exhibited some level of antibacterial activity against Staphylococcus aureus. Based on the classification by Abdullah et al. (2021), the inhibition zones were categorized as weak (less than 5 mm), moderate (5-10 mm), strong (10-20 mm), and very strong (more than 20 mm).

The negative control (soap base) showed a relatively high average inhibition zone of 9.28 mm, likely due to the antimicrobial properties of NaOH. This is consistent with previous findings by Abdullah et al. (2021), which demonstrated the effectiveness of NaOH against Gram-positive bacteria. While the positive control (soap base with triclosan) exhibited strong antibacterial activity, formulation F3 showed a moderate level of inhibition against Staphylococcus aureus, with an average inhibition zone of 7.45 mm. This indicates that the addition of coffee husk extract enhanced the antibacterial properties of the soap, particularly against Gram-positive bacteria. The thicker peptidoglycan layer in Gram-positive bacteria makes them more susceptible to the penetration of antimicrobial agents.

The antibacterial activity test against Staphylococcus aureus revealed that soap with coffee husk extract at concentrations of 2% and 4% effectively inhibited bacterial growth. This result suggests that coffee husk extract, rich in bioactive compounds such as polyphenols, could be an alternative to synthetic antibacterial agents like triclosan. Compared to previous studies, this research adds new insights into the utilization of coffee waste. While previous studies, such as those by Marcelinda et al. (2016) and Ramadhan et al. (2022), focused on the general potential of coffee by-products in cosmetic formulations, this study specifically highlights the feasibility of coffee husk extract in solid soap with defined antibacterial properties. The findings contribute to addressing the issue of coffee production waste by providing a sustainable solution that adds economic and environmental value. Utilizing coffee husk, which is often discarded as waste, reduces environmental pollution while creating innovative, high-value products. Compared to existing waste management practices like composting or simple organic fertilizer use, this approach offers a diversified application that aligns with the principles of circular economy and sustainable industry. From a scientific perspective, this study opens new avenues for exploring coffee by-products in personal care and cosmetic formulations. It validates the antibacterial properties of coffee husk extract and its compatibility with standard soap production techniques. This research can stimulate further studies on optimizing extraction methods, scaling up production, and evaluating other potential applications of coffee waste.

CONCLUSION AND SUGGESTIONS

In this study not only demonstrates the feasibility of using coffee husk extract in solid soap production but also highlights its potential to address environmental waste management issues and contribute to the development of antibacterial personal care products. This innovation aligns with global efforts to promote sustainability and provides valuable insights for the advancement of knowledge in the fields of cosmetic science and waste utilization. Based on the results of the discussion, it can be concluded that the physical characteristics of the solid soap preparation with Gayo Arabica coffee shell extract are in accordance with the standards set by SNI 3532:2021, which include organoleptic characteristics, pH test, water content, free alkali, foam stability, and antibacterial activity against staphylococcus Aureus. In the pH test, a pH value of 9.59-10.10 was obtained in all soap formulations, where the required limit was between 6-11. The results of the water content test carried out on solid soap preparations with Arabica coffee shell extract were 5.60% - 9.36%, where the required limit is a maximum of 15%. The free alkali content test results show that this soap is still safe for the skin, with an average free alkali content of 3.89.10-5 to 1.25.10-4, where the maximum free alkali content is 0.1%. The foam height test results for solid soap preparations with coffee shell extract are an average of 5-5.8 cm, with the requirement for soap foam height according to SNI 3532:2021, namely 1.3 - 22 cm. From the tests that have been carried out, it shows that each formulation has variations in the diameter of the inhibition zone against Staphylococcus Aureus in the medium category, where the average inhibition zone formed is 7.4 cm to 9.2 cm. Based on the results obtained, it shows that all formulations in this study have met the standards set by SNI 3532:2021.

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