



FORMULATION AND PHYSICAL CHARACTERIZATION OF A BODY SCRUB MADE FROM COFFEE GROUNDS TO ENHANCE ITS UTILITY AND PROMOTE SUSTAINABILITY

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Abstract

Body scrubs made from natural ingredients are an excellent choice that also supports the “back to nature” movement. One natural ingredient rich in antioxidants is coffee grounds. This study aims to characterize the physical stability of body scrub formulations containing coffee grounds. The research method consisted of two stages: the preparation of body scrub formulations and the evaluation of their physical properties. The results showed that the lemon, honey, and aloe vera variants all had a normal pH range of 4–6. The aloe vera variant exhibited the optimal pH, ranging from 5.9 to 6. Skin irritation testing revealed that none of the scrub variants showed signs of skin irritation after testing. This indicates that the formulations are safe for topical use. For the organoleptic test results, all variants appeared normal. However, the body scrub base of these formulations still needs to be optimized so that they can undergo more detailed testing.

INTRODUCTION

Indonesia is one of the world’s largest coffee producers. According to data from the International Coffee Organization (ICO), Indonesia ranks fourth among the world’s largest coffee-producing countries, behind Brazil, Vietnam, and Colombia, with production exceeding 11 million bags of coffee (approximately 660,000 metric tons). The growth of the coffee industry in Indonesia has also fueled the proliferation of local coffee shops, which have sprung up in major cities and even remote areas. High coffee consumption is accompanied by increasing waste production, particularly coffee grounds, which are often not fully utilized. One small and medium-sized enterprise (SME) processing coffee in Purwakarta District can use up to 3–5 kg of coffee grounds per day. This amount naturally results in an abundance of coffee grounds, which until now have been directly discarded in trash bins and treated merely as food/beverage waste. This raises two main issues: first, it contributes to the accumulation of organic waste that has not been properly managed; second, it represents a waste of potential alternative raw materials that could actually still be utilized.

According to several studies, coffee grounds contain antioxidants, caffeine, and natural oils that are beneficial for skin care—such as exfoliating dead skin cells, stimulating blood circulation, and helping to reduce cellulite [1]. This opens up opportunities to use coffee grounds as a base ingredient for producing body scrubs that are both economically valuable and environmentally friendly. By processing waste into body care products, we can not only address environmental issues but also create new economic opportunities and support the

growing trend toward natural beauty products. This issue requires urgent further research, as there are currently no waste management programs based on recycling or reuse.

From a theoretical perspective, this approach can be examined through the concepts of zero waste and the circular economy, which promote efficient resource utilization by processing waste into value-added products [1]. The physical instability of a cream formulation is characterized by discoloration or the appearance of color, the development of odor, phase changes or separation, formulation breakdown, changes in consistency, crystal growth, gas formation, and other physical changes. The stability of a formulation is indicated by the absence of internal phase separation, the absence of creaming, and the maintenance of good appearance, odor, color, and other physical properties [2].

Based on this background, efforts will be made to address coffee grounds waste by using them as an ingredient in a body scrub that will be formulated and physically characterized (through organoleptic testing and skin irritation testing). The goal is to produce an environmentally friendly body scrub that offers a sustainable alternative for waste management and to test an organic body scrub formulation that is beneficial for the skin.

METHOD

This research was conducted through the processes of designing and formulating a coffee grounds-based body scrub, product testing, and community outreach. In addition, there was a product testing phase, which included testing the physical characteristics and effectiveness of the body scrub—such as pH testing—conducted at the laboratories of PT. Lotte Chemical Titan Indonesia and PT. Merak Chemicals Indonesia. These laboratories were selected based on the availability of adequate facilities and infrastructure to support testing processes in accordance with scientific standards, as well as to ensure that the data obtained had a high level of validity and reliability. The data collected in this study were obtained through direct observation. The tests conducted included organoleptic testing, pH testing, and skin irritation testing.

RESULT AND DISCUSSION

The following table provides a breakdown of inputs and outputs in the wastewater treatment process:

Tabel 1. Proses Pengolahan Limbah

No	Raw Materials / Ingredients	Ingredients	Price (Rp)	Output	Description
1	Coffee Grounds	1 kg	Gratis	500 grams of coffee grounds powder (200 grams of brightening variant, 200 grams of	50% efficiency (product's main fragrance)

No	Raw Materials / Ingredients	Ingredients	Price (Rp)	Output	Description
				moisturizing variant, 100 grams of soothing variant)	
2	Granulated Sugar	1 kg	20.000	Used directly in the mixture (400 g brightening variant, 400 g moisturizing variant, 200 g soothing variant)	100% efficiency (product's exfoliating ingredient)
3	Lemon	1 kg (3 pieces)	15.000	150 ml lemon water (Use 50 ml for the brightening variant)	± 50 ml per unit (additive for the brightening variant)
4	Aloe Vera	500 grams	Gratis	100 ml aloe vera gel (Use 50 ml for the moisturizing variant)	Extraction ± 20% (additive for the moisturizing variant)
5	Olive Oil	75 ml	22.000	Used directly in the mixture (25 ml of each variant)	Already in liquid form (product solvent)
6	Honey	150 ml	19.000	Used directly in the mixture (25 ml of each variant, plus an additional 25 ml	To preserve the product (additive in the soothing variant)

No	Raw Materials / Ingredients	Ingredients	Price (Rp)	Output	Description
				specifically for the soothing variant)	
7	Packaging Cup	15 cups (approx. 150 grams each)	80.000	Use 4 cups of each color for the 3 product variants	80% efficiency (3 colors: yellow, green, pink)
Total			Rp 156.000		

The following figure provides a detailed illustration of the processing steps for aloe vera as a moisturizing additive:

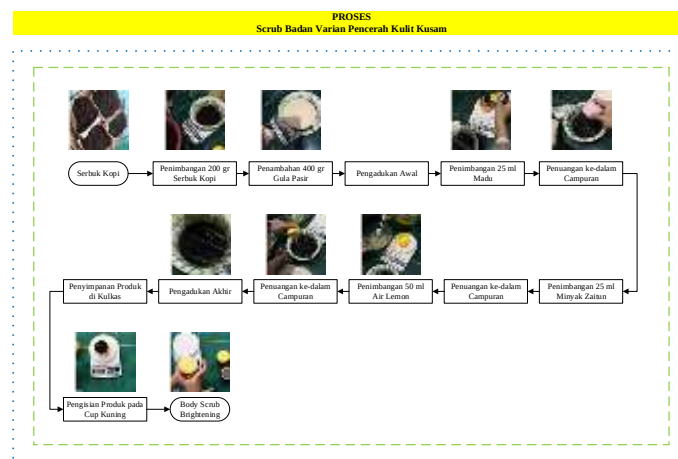


Figure 26. Body Scrub Process for Dull Skin Brightening

Initial stirring is performed to produce a homogeneous mixture and prevent uneven distribution of ingredients, which can lead to physical instability such as sedimentation or oil phase separation. Afterward, 25 ml of honey is added to the mixture. Honey contains glucose, fructose, and the enzyme glucose oxidase, which act as a humectant, a natural antibacterial agent, and a mild preservative. The enzymatic reaction that occurs—in which glucose is oxidized by oxygen to produce gluconic acid and hydrogen peroxide (H₂O₂)—helps inhibit the growth of microorganisms:

$$\text{Glucose} + \text{O}_2 \rightarrow \text{Gluconic Acid} + \text{H}_2\text{O}_2$$

Honey has been shown to inhibit the growth of microorganisms, particularly at low pH and high moisture levels, making it an effective microbiological stabilizer in natural scrubs.

The next step is to add 50 ml of lemon juice, squeezed from three fresh lemons. Lemon is used as a brightening agent because it contains ascorbic acid, or vitamin C ($C_6H_8O_6$), which acts as an antioxidant and tyrosinase inhibitor, thereby suppressing the formation of melanin that causes hyperpigmentation. The reaction can be explained as:

Vitamin C + Tyrosinase $\rightarrow$ Enzyme Activity Inhibition $\rightarrow$ Decreased Melanin Production

Natural vitamin C can enhance the skin-brightening effect by up to 25% after two weeks of use. Therefore, lemon supports the brightening function while maintaining the product's antioxidant stability.

Next, 25 ml of olive oil is added. This oil acts as a natural emollient and solvent containing oleic acid ($C_{18}H_{34}O_2$) and tocopherol (vitamin E). Olive oil deeply moisturizes the skin, dissolves active particles, and supports the penetration of active ingredients. Additionally, it binds the particles together to prevent separation, thereby maintaining the product's consistency during storage. Andrikopoulos et al. reported that olive oil can increase skin moisture retention by up to 38% when used in topical products.

After all ingredients were added, final mixing or homogenization was performed to ensure the mixture was evenly blended and stable. This homogenization prevents phase separation or changes in texture. The product was then stored in a refrigerator at 3°C for 24 hours to inhibit microbial growth in the early stages. Finally, the product is packaged in 150-gram yellow plastic cups that are airtight and oil-resistant, ensuring the product's stability until the testing phase. Below is a detailed illustration of the coffee powder processing steps for the moisturizing body scrub variant for dry skin:



Figure 2. Body Scrub Process for Dry Skin Moisturizing Variants

Based on the diagram above, the process of creating a moisturizing variant of this body scrub product uses coffee grounds as the main ingredient, combined with additional ingredients such as granulated sugar, honey, olive oil, and aloe vera gel. Each ingredient is carefully selected and formulated to produce a product that not only exfoliates but also maximizes skin hydration. The first step begins with selecting dried coffee grounds as the primary base ingredient. Coffee grounds were chosen because their caffeine content ($C_8H_{10}N_4O_2$) enhances microcirculation on the skin's surface and acts as a natural anti-inflammatory agent. The micro-coarse

texture of the coffee grounds makes them an effective physical exfoliant for removing dead skin cells. Research shows that coffee grounds possess exfoliating power comparable to commercial apricot kernel-based scrubs, with the added benefit of natural antioxidant content [3].

After weighing out 200 grams, the coffee grounds are mixed with 400 grams of granulated sugar (a 2:1 ratio), serving as both an additional exfoliant and a humectant. The sucrose ($C_{12}H_{22}O_{11}$) in the sugar helps draw moisture from the environment to the skin's surface, aiding in hydration. The combination of sugar and coffee provides a gentler yet effective exfoliating effect. This coffee-and-sugar scrub blend has been shown to increase skin moisture by up to 15% more than using coffee alone [4].

The mixture is then stirred thoroughly at the initial stage to ensure homogeneity. This stirring is essential to prevent ingredient segregation during subsequent steps. Once thoroughly mixed, 25 ml of honey is added to the mixture. Honey is a multifunctional ingredient because it contains glucose, fructose, and the enzyme glucose oxidase, which can produce gluconic acid and hydrogen peroxide (H_2O_2) through an enzymatic reaction:



According to Al-Waili et al. (2011), honey has been shown to inhibit the growth of microorganisms, particularly at low pH and high moisture content, making it an effective microbiological stabilizer in natural scrubs.

The main components of this oil include oleic acid ($C_{18}H_{34}O_2$) and vitamin E (tocopherol), which act as emollients to soften and nourish the skin. Additionally, this oil helps bind solid and liquid ingredients in the formulation, preventing phase separation. Studies show that pure olive oil can increase skin moisture retention by up to 38% when formulated into topical products [5].

After adding the olive oil, the mixture is stirred again to enhance its stability. Next, 25 ml of aloe vera gel is added. Aloe vera contains bioactive compounds such as polysaccharides, vitamins A, C, and E, as well as enzymes like bradykininase, which aid in wound healing and skin hydration. Its primary polysaccharide, acemannan, acts as a humectant as well as an anti-inflammatory and skin protectant. A common chemical reaction that occurs when aloe vera is added—particularly related to antimicrobial stability and hydration—is the interaction of polysaccharides with water to form a hydrophilic gel that maintains moisture through water retention:



A study by Syamsuddin et al. (2023) noted that aloe vera has significant moisturizing effects and also contains anthraquinone compounds such as aloin, which provide antibacterial effects and accelerate skin cell regeneration. A final mixing process (homogenization) is performed to ensure that all active ingredients are evenly distributed throughout the mixture. This homogenization is crucial to prevent phase separation, ingredient precipitation, or the formation of an unwanted oil layer. Afterward, the mixture is stored in a refrigerator at 3°C for 24 hours to stabilize its physical structure and prevent the growth of microorganisms in the early stages [6]. The final step is packaging the product into 150-gram green plastic cups that are airtight and

oil-resistant. This packaging was chosen to protect the contents from external contamination while maintaining product quality until testing.

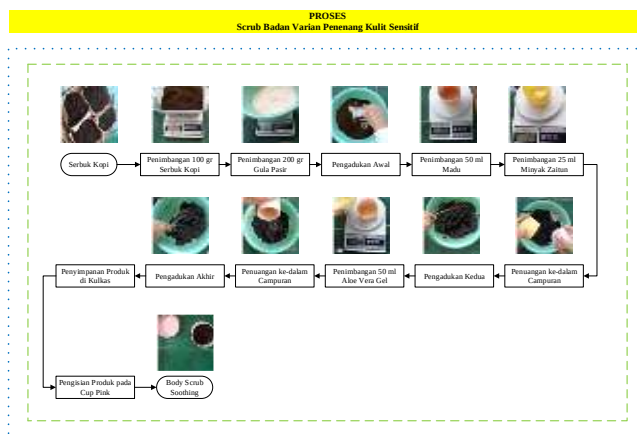


Figure 28. Production Process for the Soothing Variant of the Body Scrub for Sensitive Skin

Based on the diagram above, the production process for the soothing variant of this body scrub uses coffee grounds as the main ingredient, combined with additional ingredients such as granulated sugar, honey, olive oil, and aloe vera gel. Each ingredient is carefully selected and formulated to create a product that not only exfoliates but also soothes and maximizes the skin's moisture retention. The first step involves selecting dried coffee grounds as the primary base ingredient. Coffee grounds were chosen because their caffeine content ($C_8H_{10}N_4O_2$) can improve microcirculation on the skin's surface and act as a natural anti-inflammatory agent. The micro-coarse texture of the coffee makes it an effective physical exfoliant for removing dead skin cells.

1. Organoleptic Testing of Body Scrub Products

Organoleptic testing was conducted subjectively by 6 respondents using their senses of sight, smell, and touch to evaluate each scrub variant

Table 2. Summary of Organoleptic Test Results

Appraiser	Varian	Color	Aroma	Tekstur	Konsistensi
R1	Lemon (Bright ening)	4	4	5	5
R2		4	4	5	5
R3		5	4	4	5
R4		4	5	5	5
R5		5	5	4	5
R6		5	3	3	5
Total		27	25	26	30
Average		4,5	4,167	4,33	5
R1	Aloe vera (Moistu rizing)	5	5	4	5
R2		5	5	4	4
R3		5	4	4	5
R4		5	4	5	5
R5		5	4	5	5
R6		5	3	4	5

Total		30	25	26	29
Average		5	4,167	4,33	4,83
R1	Esktra Madu (Soothi ng)	5	5	5	5
R2		5	3	4	4
R3		5	4	4	5
R4		4	4	5	5
R5		5	4	5	5
R6		5	3	4	5
Total		29	23	27	29
Average		4,83	3,83	4,5	4,83

Based on the table above, the organoleptic scores for each product variant are as follows:

Brightening Body Scrub:

- Color: 4.5 — The product's color appearance meets expectations
- Scent: 4.2 — The strength and pleasantness of the active ingredient's scent are appropriate
- Texture: 4.3 — The coarseness of the granules is appropriate
- Consistency: 5 – The mixture's viscosity is very appropriate

Moisturizing Body Scrub:

- Color: 5 – The product's color appearance is very much in line with expectations
- Aroma: 4.3 – The strength and pleasantness of the active ingredient's aroma are appropriate
- Texture: 4.2 – The coarseness of the granules is appropriate
- Consistency: 4.8 – The mixture's viscosity is very appropriate

Soothing Body Scrub:

- Color: 4.8 – The product's color meets expectations very well
- Scent: 3.8 – The strength and pleasantness of the active ingredient's scent are appropriate
- Texture: 4.5 – The coarseness of the granules is appropriate
- Consistency: 4.8 – The mixture's viscosity is very appropriate

1. pH Testing of Body Scrub Products

The pH test aims to determine the acidity or alkalinity of each body scrub variant, as the pH value has a significant impact on skin comfort, the potential for irritation, and the product's microbiological stability. The test was conducted using a digital pH meter calibrated with standard buffer solutions of pH 4.00, pH 7.00, and pH 10.00 to ensure the accuracy of the measurement results.

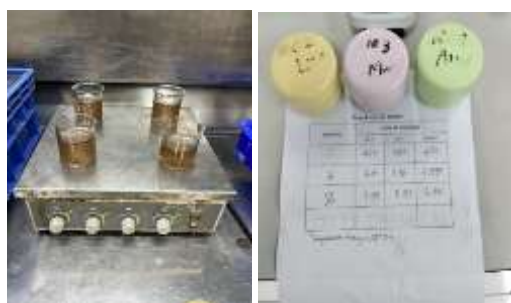
This testing procedure follows the 10% w/v dilution method commonly used in cosmetic and skin care product testing [7]. A 5-gram sample of scrub from each variant was weighed and dissolved in 50 ml of sterile distilled water in a beaker, then stirred until homogeneous for approximately 2 minutes. The pH meter electrode was then immersed in the solution at room temperature ($\pm 25^{\circ}\text{C}$), and a reading was taken once the pH value had stabilized.

The ideal pH range for cosmetic and skin care products is between 4.5 and 6.5, as this range most closely approximates the physiological conditions of healthy human skin. This range is considered safe and does not cause skin irritation [8], as also confirmed in a study by Putri et al., which found that topical formulations with a pH of 4.5–6.5 remain within the skin's tolerance limits and do not impair skin barrier function [9]. The following table presents the pH measurement results for each body scrub variant:

Table 3. pH Measurement Results

Kode	Varian	pH ke-1	pH ke-2	Rata-Rata
I	Lemon	4,54	4,52	4,53
II	Aloe Vera	6,00	5,95	5,975
III	Esktra Madu	5,90	5,91	5,905

Based on the results of the tests conducted at the laboratory, as follows:



Gambar 3. (a) Pengujian pH dan (b) Hasil Pengukuran pH

Based on the test results, all body scrub variants fell within the normal pH range in accordance with skin safety standards. Although the lemon variant had a pH value of 4.53—slightly lower than the other variants—this value still falls within the normal skin pH range (4.5–6.5) and therefore does not pose a risk of irritation [7]. This is consistent with the findings of Yuliani et al. (2019), who stated that formulations with a pH close to 4.5 are still well-tolerated by the skin and do not trigger adverse reactions, particularly for products applied topically for a short period of time, such as body scrubs [10].

1. Skin Irritation Testing

This test was conducted to evaluate the skin's reaction to the use of the scrub under normal conditions. The test was performed on each variant using the following method:

1. Test area: the inner back of the hand (a sensitive area representative of topical testing).
2. The scrub product for each variant was applied evenly.
3. Left on for 15 minutes without rubbing or rinsing.
4. After 15 minutes, the product was rinsed off with running water, then observed for 1 hour to check for:
 - Redness
 - Itching
 - Burning sensation
 - Swelling



Figure 4. Skin Irritation Test Procedure

Test results showed that none of the scrub variants exhibited signs of skin irritation after testing. This indicates that the formulations are safe for topical use.

CONCLUSION

Based on the results of the study, it can be concluded that processing coffee grounds into a body scrub yielded the following results: The study showed that the lemon, honey, and aloe vera variants all had a normal pH range of 4–6. The aloe vera variant exhibited the optimal pH range, with values between 5.9 and 6. Skin irritation test results showed that none of the scrub variants exhibited signs of skin irritation following testing. This indicates that the formulation is safe for topical use. For organoleptic test results, all variants appeared normal. However, the body scrub base of the formula still needs to be optimized so that it can be tested more thoroughly. All ingredients used are natural and free of synthetic chemicals. The processing is carried out manually and hygienically, resulting in a high-quality and environmentally friendly product.

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