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Formulation, Characterization, and Antibacterial Activity of Solid Soap Containing Guava Leaf Extract (*Psidium guajava* L.) and Precipitated Calcium Carbonate

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ABSTRACT

Bath soap is defined as a sodium compound with fatty acids used as a body cleanser, which generates foam and does not cause skin irritation. Beyond cleansing the skin from external dirt, soap can also function to eliminate bacterial skin infections. Prior investigations have verified that the saponins, tannins, and flavonoids concentrated in guava leaves exhibit robust antibacterial activity. The objective of this study was to determine the physicochemical properties of a solid soap formula containing the ethanol extract of guava leaf and precipitated calcium carbonate, including texture, color, pH, moisture content, hardness, and other relevant properties. This study employed a laboratory experimental research method. The procedure involved the preparation of guava leaf (*Psidium guajava* L.) simplicia, followed by extraction with a 70% ethanol solvent via maceration. Subsequently, the solid soap formulation was created using the guava leaf extract and precipitated calcium carbonate, followed by evaluation and antibacterial activity testing against *Staphylococcus aureus* bacteria. The pH evaluation test yielded an average value of 9.09 for the blank formula, while the average pH values for the active formulas were 9.13 for FI, 9.30 for FII, 9.23 for FIII, and 9.12 for the positive control (comparator). Based on the antibacterial testing results, the solid soap containing guava leaf ethanol extract demonstrated strong antibacterial activity against *Staphylococcus aureus*. The inhibition zone diameters were recorded as 0 mm for F0 (blank), 11.6 mm for FI (10% concentration), 10.9 mm for FII (15% concentration), 11 mm for FIII (20% concentration), and 11.3 mm for K+ (comparator). The research indicates that the ethanol extract of guava leaves combined with precipitated calcium carbonate (PCC) can be successfully formulated into a stable solid soap that meets the physical quality standard requirements according to the Indonesian National Standard (SNI).

Keywords: Solid soap, guava leaf (*Psidium guajava* L.*)*, Precipitated Calcium Carbonate

INTRODUCTION

Skin is one of the most critical organs of the human body, serving to protect the internal systems from physical or mechanical trauma, heat, cold, germs, and bacteria. Positioned on the outermost layer of the body, the skin acts as a protective shield for tissues and organs.

Given this vital protective function, proper care and skin protection are essential, one approach being the regular use of cosmetics (Rusli, N., 2019).

As the primary barrier covering the body surface, healthy skin conditions significantly bolster an individual's self-confidence. If the structural integrity of the skin is compromised or wounded, it creates a point of entry for microorganisms or pathogens that induce infectious diseases. One of the primary bacterial pathogens responsible for these skin infections is *Staphylococcus aureus* (Hidayah, H., 2023).

Globally, more than half of the infectious diseases and mortality cases among children under five are caused by pathogens entering the mouth via contaminated food, water, and unsanitary hands. Many of these pathogens originate from human and animal feces. Deficient personal hygiene and environmental sanitation, compounded by a lack of clean water supplies, lead to 88% of child deaths worldwide from diarrhea, nearly 90% of whom are children under five. Studies have demonstrated that neglecting to wash hands increases the relative risk of contracting diarrhea by 95%. Conversely, washing hands thoroughly with soap can substantially reduce the risk of diarrheal diseases down to just 4%. Consequently, there is a profound correlation between handwashing behavior using soap and the incidence of diarrheal diseases (Nurwaini, S., 2018).

Bath soap is defined as a sodium compound paired with fatty acids that is utilized as a skin and body cleanser, possesses foaming capabilities, and does not irritate the skin. The quality specifications for bath soap established by the Indonesian National Standard (SNI) stipulate that solid soap must have a maximum moisture content of 15%, a maximum free alkali content of 0.1%, and a free fatty acid content of less than 2.5%. Solid bath soap is a product generated through the saponification reaction between a strong base (NaOH) and the fatty acids derived from vegetable oils.

Beyond standard cleansing from external impurities, soap can also be formulated to eliminate bacterial infections from the skin. Soap capable of eradicating bacteria is known as antiseptic or antibacterial soap. Antiseptic soaps contain dedicated active ingredients that function as antibacterial agents, reducing the load of harmful bacteria on the skin surface. A high-quality antiseptic soap must satisfy specific baseline standards: first, it must effectively eliminate dirt and pathogens; second, it must preserve skin health, as intact, healthy skin is a foundational element of the human immune system (Cahyaningrum,P.L., 2020) .

Indonesia possesses a rich biodiversity of flora with proven therapeutic benefits, including guava plants. Guava leaves (*Psidium guajava* L.) contain active phytochemical compounds that serve as potent antibacterial agents, making them a viable alternative to natural antibiotics. Guava leaves harbor secondary metabolites such as flavonoids, tannins, saponins, polyphenols, essential oils (eugenol), malic acid, ursolic acid, psidiolic acid, crataegolic acid, oleabolic acid, and guajaverin. Prior investigations have verified that the saponins, tannins, and flavonoids concentrated in guava leaves exhibit robust antibacterial activity (Widiastuti, T.C., 2023).

An antibacterial agent is a substance that kills or inhibits the proliferation of bacteria, serving as an antimicrobial drug targeting organisms detrimental to human health. Bacteria responsible for creating body odor and associated skin infections include *Staphylococcus epidermidis, Staphylococcus aureus, Streptococcus pyogenes, Cutibacterium acnes, and Pseudomonas aeruginosa*. Guava leaves represent an effective, naturally sourced antibacterial alternative against these strains (Goetie, I.H., 2022).

Precipitated Calcium Carbonate (PCC, $CaCO_3$) functions in cosmetic formulations as a physical blocker. It operates by reflecting ultraviolet (UV) radiation, creating an opaque protective layer on the skin's surface, and simultaneously serving as a reinforcing structural filler (Hasyim,I.M., 2015.. Calcium carbonate is an abundant inorganic compound, making up more than 4% of the Earth's crust. It is widely utilized across various manufacturing industries, including paper, plastics, inks, paints, polymer piping, ceramics, and cosmetics, alongside medical and food applications (Warsy, W., 2016)

Other carbon-dense agricultural materials, such as oil palm shells, are frequently converted into activated charcoal for cosmetic additions. Activated charcoal is a porous solid structure utilized as a supporting material in cosmetic products, including solid soaps. In prior research by Handayani et al. (2017), it was demonstrated that guava leaf extract successfully suppressed the growth of *Streptococcus mutans*, the primary causative bacterium behind dental plaque, using extract concentrations of 2.5%, 3%, and 3.5%. Furthermore, a study by Meisani et al. (2018) evaluating a deodorant formulation containing guava leaf ethanol extract at concentrations ranging from 1% to 50% demonstrated significant inhibitory zones against Staphylococcus epidermidis on Mueller-Hinton Agar (MHA) mediums compared against a chloramphenicol standard.

The primary objectives of this research were to characterize the physicochemical properties of a solid soap formula incorporating guava leaf ethanol extract and precipitated calcium carbonate—specifically assessing texture, color, pH, moisture content, and structural hardness—and to verify its efficacy in inhibiting the growth of Staphylococcus aureus to establish its viability as an antibacterial soap.

METHODS

This study utilized a laboratory experimental design. The scope of work encompassed the processing of guava leaf raw materials into dry simplicia, extraction via maceration using a 70% ethanol solvent, formulation of solid soap variants loaded with the extract and precipitated calcium carbonate (PCC), and subsequent physicochemical evaluation alongside in vitro antibacterial screening against *Staphylococcus aureus*.
The experimental work was carried out at the Laboratory of Cosmetology and Microbiology, Faculty of Pharmacy, Institut Kesehatan Helvetia, Medan.

Research Apparatus: The laboratory instruments utilized included an analytical balance, thermometer, wooden clamps, Petri dishes, Bunsen burners, inoculation loops (ose), tweezers, test tubes, test tube racks, aluminum foil, autoclave, stirring rods, porcelain dishes, Erlenmeyer flasks (Pyrex) 100 mL, graduated cylinders (Pyrex) 5 mL, 10 mL, 50 mL, and 250 mL, incubator, drying oven, water bath, rotary evaporator, metal spoons, pH meter, glass slides, wool thread, blender, hand mixer, parchment paper, blank antibiotic discs, Laminar Air Flow (LAF) cabinet, filter paper, glass funnels, soap molds, and product packaging.

Research Materials: The essential materials comprised the ethanol extract of guava leaves (*Psidium guajava* L.), isolates of Staphylococcus aureus, 70% ethanol, coconut oil, olive oil, palm oil, lemon fragrance oil, precipitated calcium carbonate (PCC), distilled water (aquades), Asepso antiseptic soap (positive control), 0.9% NaCl solution, Sodium Hydroxide (NaOH), 1% H_2SO_4, 1% $BaCl_2$, Hydrochloric acid (HCl), Nutrient Agar (NA) medium, chloroform, Magnesium powder, $FeCl_3$, Na_2SO_4, and n-hexane.

Solid Soap Manufacturing Procedure: The solid soap preparation followed a cold/semi-hot saponification technique. NaOH pellets were dissolved thoroughly in distilled water. Separately, the oil phase—consisting of coconut oil, olive oil, and palm oil—was blended and heated until reaching a stable temperature of 70°C. The aqueous NaOH solution was then added slowly to the oil mixture while being agitated continuously using a hand mixer until a homogeneous emulsion was achieved. Precipitated calcium carbonate was introduced into the batch and mixed thoroughly until the mixture reached a 'trace' state (the point at which the soap mass thickens into a pudding-like consistency). The guava leaf ethanol extract and lemon fragrance oil were incorporated precisely at this trace stage and stirred until completely uniform. Finally, the fluid soap mass was poured into dedicated molds and left to cure at room temperature for 24 hours until fully solidified.

RESULTS AND DISCUSSION

Table 1. Organoleptic Evaluation Results

Formula	Physical Form	Color	Scent
F0 (Blank)	Solid	White	Lemon
F1 (10%)	Solid	Light Brown	Lemon
F2 (15%)	Solid	Brown	Lemon
F3 (20%)	Solid	Dark Brown	Lemon
Comparator (K+)	Solid	Green	Aromatic

The organoleptic assessment detailed in Table 1 establishes that all formulated batches successfully attained a solid form. This assessment aimed to ascertain the physical stability and overall viability of the solid soap preparations. The baseline soap matrix (blank formulation) exhibited a standard white appearance characterized by a distinctive lemon fragrance. Upon integration of the active guava leaf extract, the formulations transformed to light brown and dark brown shades corresponding to the respective extract concentrations, while successfully maintaining the desired lemon aroma profile across all groups.

Table 2. Structural Hardness Test Results

Formula	Trial 1 (kg)	Trial 2 (kg)	Trial 3 (kg)	Average Hardness (kg)
F0	3	4	4	3.6
F1	2	2.5	2.5	2.3
F2	2	2	2	2.0
F3	2	2	3	2.3
K+	2	2	2.5	2.1

The mechanical hardness data in Table 2 reveals that the blank formula (F0) possessed the highest average structural hardness at 3.6 kg. The addition of the plant extract modified the inner structure, yielding stable average values of 2.3 kg for F1, 2.0 kg for F2, and 2.3 kg for F3, aligning closely with the commercial positive control (2.1 kg).

The incorporation of *Psidium guajava* L. leaf extract alongside precipitated calcium carbonate significantly enhanced the structural firmness of the soap matrix. Based on the mechanical performance profile, a lower empirical instrument value correlates inversely with higher physical hardness. Consequently, the data implies that increasing the concentration of the active ingredients structurally reinforces the solid preparation. Furthermore, conducting hardness testing post-curing is highly recommended, as the saponification and crystallization processes mature during this phase, allowing the solid soap to reach a stable and durable structural equilibrium.

Table 3. Soap pH Test Results

Formula	pH I	pH II	pH III	Average pH	SNI Standard (9-11)
F0	9.04	9.10	9.13	9.09	Compliant
F1	9.07	9.16	9.17	9.13	Compliant
F2	9.25	9.31	9.34	9.30	Compliant
F3	9.20	9.23	9.26	9.23	Compliant
K(+)	9.09	9.12	9.15	9.12	Compliant

According to the Indonesian National Standard (SNI), the acceptable pH range for solid bath soaps is between 9 and 11. As shown in Table 3, all prepared formulations fell securely within this normative range, recording average pH levels of 9.09 (F0), 9.13 (F1), 9.30 (F2), and 9.23 (F3). Maintaining an alkaline pH around 9 is critical for optimizing cleansing efficacy, as alkaline environments facilitate the emulsification and dissolution of sebum, cutaneous lipids, deeply embedded dirt particles, and other organic residues accumulated on the epidermal surface (Susanti, M.M., 2021)

Table 4. Foam Height Test Results

Formula	Trial I (cm)	Trial II (cm)	Trial III (cm)	Average Height (cm)	SNI Standard (1.3-22 cm)
F0 (Blank)	14	13	13	13.3	Compliant
F1 (10%)	13	13	12	12.6	Compliant
F2 (15%)	15	15	13	14.3	Compliant
F3 (20%)	13	13	12	12.6	Compliant
K+	14.5	14	14	14.1	Compliant

The foam profiling experiments detailed in Table 4 indicate that the average foam heights generated by the formulas were 13.3 cm (F0), 12.6 cm (F1), 14.3 cm (F2), and 12.6 cm

(F3). These findings confirm full compliance with the SNI 06-3532-1994 reference limits of 1.3 to 22 cm, indicating excellent lathering performance.

Moisture Content Analysis: Pursuant to the national quality standards set forth in SNI 06-3532-1994, the maximum allowable moisture content for solid toilet soaps is capped at 15%. The analytical principle governing moisture determination in these solid soap matrices relies on gravimetric measurement following thermal drying at 105°C for a duration of 30 minutes. Strict monitoring of moisture content is imperative due to its direct, cascading impact on the soap's chemical stability and physical longevity (Basir, H., 2023). The gravimetric assessment indicated that Formula 0 (blank) possessed a moisture content of exactly 15%, whereas Formula I, Formula II, and Formula III exhibited moisture levels of 11%, 14%, and 13%, respectively. Remarkably, all experimental formulations complied fully with the standard threshold by maintaining moisture levels below the 15% statutory ceiling.

Table 5. Hedonic Consumer Preference Test Results

Evaluation Category	F0 (%)	F1 (%)	F2 (%)	F3 (%)
Color	84.00	82.67	94.67	88.00
Aroma	70.67	76.00	96.00	80.00
Texture	80.00	78.67	92.00	78.67
Average Preference	**78.22**	**79.11**	**94.22**	**82.22**

Hedonic testing involving 15 human panelists (Table 5) demonstrated that Formula 2 (15% extract) was highly favored by consumers, achieving a peak average satisfaction score of 94.22%. Panelists highlighted its superior visual appearance, appropriate texture, and balanced scent profile compared to alternative batches.

Skin Irritation and Safety Screening: In vivo skin patch screening conducted on the retroauricular region of volunteers for 15 minutes confirmed that none of the solid soap formulations caused any adverse dermatological reactions, such as erythema (redness), pruritus (itching), or edema (swelling). This safety profile is attributed to the optimized pH of the soap blending seamlessly with natural skin tolerances.

Table 6. Antibacterial Inhibition Zones Against Staphylococcus aureus

Formula	Trial I (mm)	Trial II (mm)	Trial III (mm)	Average Inhibition Zone (mm)	Inhibition Category

Blank F0	0.0	0.0	0.0	0.0	Weak / No Activity
Positive Control (K+)	12.7	12.4	8.8	11.3	Strong
F1 (10%)	13.3	10.5	11.1	11.6	Strong
F2 (15%)	13.0	10	9.7	10.9	Strong
F3 (20%)	12.9	10.5	9.8	11.0	Strong

The antibacterial assay evaluating the solid soaps infused with *Psidium guajava* L. ethanolic extract and precipitated calcium carbonate revealed substantial zones of inhibition against the target pathogen. Formula I (10%) produced an average inhibition zone diameter of 11.6 mm; Formula II (15%) yielded 10.9 mm; Formula III (20%) demonstrated 11.0 mm; and the positive control exhibited a mean zone of 11.3 mm. All four test groups fall under the "strong" antibacterial inhibition category. Conversely, the negative control (Formula 0, base matrix) exhibited no clear zone around the well, registering a completely negative (-) result.

These findings clearly substantiate that the incorporation of guava leaf extract combined with precipitated calcium carbonate imparts powerful antibacterial activity against *Staphylococcus aureus*, as evidenced by the well-defined zones of inhibition on the nutrient agar medium. The underlying mechanism is driven by the potent bioactive phytochemical constituents inherent to the *Psidium guajava* L. extract, which exert robust inhibitory dynamics against the proliferation of gram-positive *Staphylococcus aureus* strains (Handarni, D., 2020).

Statistical evaluation via One-Way Analysis of Variance (ANOVA) confirmed a highly significant difference in antibacterial efficacy between the test groups, yielding a significance value of $p = 0.000$ ($p < 0.05$). This strongly verifies that the concentration variations of the guava leaf extract directly influenced the antibacterial performance of the finished soaps.

CONCLUSION

The ethanol extract of guava leaves (*Psidium guajava* L.) combined with Precipitated Calcium Carbonate (PCC) can be successfully manufactured into stable, high-quality solid soaps that fully comply with the physical and chemical quality standard requirements according to the Indonesian National Standard (SNI).

The formulated solid soaps possess potent, scientifically verified antibacterial properties against *Staphylococcus aureus*, displaying substantial clear zones of inhibition across all active extract concentrations (10%, 15%, and 20%). All test groups fall under the "strong" antibacterial inhibition category.

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