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Halal soap enriched with clay for cleansing purposes

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Abstract

Two varieties of halal soaps—body and laundry—were developed by incorporating various types of clays to effectively cleanse severe najis (impurities) in adherence to Islamic principles. Four clays-kaolin, white clay, bentonite, and clay loam, were tested individually at concentrations ranging from 5% to 20% w/w. Selection of the optimal formulation was based on physical, chemical, and sensory characteristics. The results indicated that a 20% w/w concentration of kaolin clay was the most suitable for both soap types. At this composition, the soap provided an appropriate pH, strong foam production, and foam stability, meeting most requirements for industrial soap standards. Both body and laundry soaps enriched with kaolin received high satisfaction ratings for cleanliness and non-irritation. The incorporation of kaolin in soap, along with its high pH, exhibited bactericidal effects against both *Staphylococcus aureus* and *Escherichia coli*. The turbidity of the soap solution confirmed the presence of clay particles during use. In conclusion, the halal soap formulations align with religious cleansing requirements and suit the lifestyle of modern consumers worldwide.

Keywords: clay soaps, halal soaps, kaolin, najis cleansing,

1. Introduction

One of the principles of Islam emphasizes cleanliness for purifying oneself from impurities, known as *najis*, before praying and performing religious duties [1]. In daily life, there is a possibility of contact with impurities, which are categorized into three levels: light, such as contact with the urine of boys under two years old; medium, such as contact with blood contaminated by viruses or epidemics, or with vomit; severe, such as contact with pigs or a dog's saliva. [2]. The prescribed purification process involves multiple steps, including washing the affected area seven times with clean water, with the final rinse incorporating water mixed with pure clay [1-2]. These steps are essential and must be followed thoroughly. However, offering alternatives for busy routines provides a modern option that aligns with religious principles, allowing for quick purification before a more thorough cleansing at home when time permits [3-4].

Recent research has focused on the development of clay-based soap formulations, studying the use of various clays [5], such as bentonite, which has been reported for use in cosmetics and pharmaceuticals [6]. Kaolin has also been investigated for its potential to enhance the

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effectiveness of clay-based soaps in the removal of najis (ritually impure substances) [7]. White clay, known for its smooth texture and clean feel, has been reported for use in cosmetics and medical treatments [8-9]. The porous structure of these clays contributes to the cleansing efficacy, and their inherent antimicrobial properties make clay soaps versatile for a variety of purposes [9-10]. However, the antibacterial activity of clay can vary significantly depending on mineral composition, particularly the presence of elements such as iron (Fe), zinc (Zn), copper (Cu), and nickel (Ni), which are considered key factors influencing the mechanisms underlying its antibacterial properties [11].

Globally, there is a growing interest in developing halal-compliant soaps that integrate natural ingredients and various clay types to meet consumer expectations for both efficacy and religious adherence. For instance, Kassim et al. (2014) [1] evaluated different clay samples for their suitability in halal soap manufacturing, while Iriany et al. (2020) [12] demonstrated that 15% kaolin in palm oil-based soap provided product firmness across temperature variations and fulfilled Indonesian National Standards (SNI). Despite these findings, research on clay-based soaps remains limited and outdated in Thailand, with most studies focusing on liquid formulations [13-14] and few exploring bar soaps enriched with volcanic clay [15].

This research aims to develop halal clay bar soaps using locally sourced Thai clays, addressing the challenge of formulating products that meet both functional and religious requirements. The study focuses on optimizing formulations for two types of soap: a body cleansing soap for personal hygiene and a laundry soap for washing fabrics, each utilizing ratios of oils mixture phase and alkaline bases from our previous study [16]. Four types of clay—kaolin, white clay, bentonite, and clay loam—were incorporated to evaluate their effectiveness to identify the best type and proportion of clay that meets user requirements and aligns with industrial guidelines for soap production. The soaps were assessed based on physical and chemical properties, as well as feedback from religious experts and volunteer users, to identify the most suitable clay type and optimal content for practical, religiously compliant use.

2. Methodology

2.1 Preparation of Soap Formulation

A consistent combination of oils—coconut, palm kernel, rice bran, and palm olein in a ratio of 1:1:1.5:2— was used as the oil phase for body soap. The formulation consisted of 23 grams of water, 9 grams of sodium hydroxide (NaOH), and 65 grams of the oils phase. Once the mixture reached the desired consistency, it was poured into a mold and allowed to set for 24 hours. After hardening, the soap was characterized by its physical and chemical properties. Clay proportions were adjusted to optimize soap properties, and all experiments were conducted in triplicate to ensure reproducibility. The laundry soap preparation followed a similar process, with palm kernel oil as the primary oil. The preparation of laundry soap followed a similar process, with a key difference in the oil phase. For the cleansing soap, only palm kernel oil was used as the oil phase. The formulation comprised 23 grams of water, 9 grams of sodium hydroxide, and 65 grams of palm kernel oil.

2.2 Foam Volume and Stability Test

A 1% aqueous soap in water was transferred into a 100 mL graduated cylinder. After sealing and inverting the cylinder 50 times, foam volume was measured after 1 minute. Foam stability was measured by the time taken for the foam to dissipate.

2.3 pH measurement

The pH of a 1% soap solution was measured using a calibrated pH meter.

2.4 Surface Slickness and Corrosion Rate

Surface slickness was evaluated by washing a soap sample in water for 45 minutes, and then drying it overnight. The slickness was assessed by squeezing the soap between the thumb and forefinger.

To determine the corrosion rate, 10 grams of soap were submerged in water at 40°C for one minute and lathered in circular motions for 20 rounds. This process was repeated four times daily for three days. The corrosion rate was calculated using the formula:

Corrosion Rate = $(w_o - w_t) \times 100/w_o$, where w_o and w_t represent the initial weight and the final of the soap.

2.5 Total Fat Content

Dissolve 5 grams of soap in 100 mL of hot water, acidified, and extracted with petroleum ether. Wash the ether layer with water, evaporate, and titrate with potassium hydroxide. Wash and dry the produced potassium soap. The total fat content was calculated as:

Total Fat Content (%) =$[\mathrm{m}_1 - (\mathrm{VxNx0.038})]\frac{100}{\mathrm{m}_0}$: where m_o is the initial weight of the soap sample, m_1 is the weight of the potassium soap, V is the volume of ethanolic potassium hydroxide used in milliliters, and N is the normality of the potassium hydroxide solution.

2.6 Free Sodium Hydroxide

Reflux soap sample in ethanol at room temperature and titrated with ethanolic hydrochloric acid. Free hydroxide was calculated as:
Free Hydroxide (%) = $\frac{MW_{NaOH}}{\mathrm{m\ x\ 1000}}$ $\mathrm{xVxNx100}$; where V is the volume of ethanolic hydrochloric acid used in milliliters, N is the normality of the ethanolic hydrochloric acid, m is the weight of the soap sample in grams, a molecular weight of NaOH is 40 $g.mole^{-1}$.

2.7 Insoluble Substances in Ethanol

Dissolve the soap sample in 95% ethanol, filter, dry, and weigh to calculate insoluble material as: Insoluble in Ethanol (%) = $m/m_o \times 100$; where m is the weight of the insoluble substances in grams and m_o is the initial weight of the soap sample in grams.

2.8 Unsaponifiable Matter

The soap sample was refluxed with ethanol and potassium hydroxide (KOH) for 30 minutes, followed by extraction with diethyl ether, washing, and drying. Unsaponifiable matter was calculated as: Unsaponifiable Matter (%) = (100 x A)/M; where A is the weight of the dried residue and M is the initial weight of the soap sample in grams.

2.9 Chloride Content

A portion of soap was dissolved in water. Potassium chromate was then added. Titrate the mixture with 0.1 N silver nitrate until a red precipitate formed. Chloride percentage was calculated as: Chloride (%) = $\frac{\mathrm{V\ x\ N\ x\ 5.84}}{w_s}$; where V and N are the volume (mL) and normality of Std. Silver nitrate, respectively, and w_s is the weight of the soap sample in grams. 5.84 is a constant derived from the equivalent weight of the chloride ion (Cl^-) when titrated with $AgNO_3$

2.10 Minimum Inhibitory Concentration (MIC) and Minimum Bactericidal Concentration (MBC)

The MIC was determined by broth microdilution in 96-well plates using antimicrobial serial dilutions in DMSO with Mueller-Hinton Broth, inoculated with *S. aureus* or *E. coli* and incubated at 35–37°C for 18–24 hours. MIC was defined as the lowest concentration preventing visible growth [17]. For MBC, soap dilutions (1, 2, 4, 8, 16, 32, 64 mg/mL) in cation-adjusted Mueller-Hinton Broth were inoculated with 10^5 CFU/mL bacteria, incubated at 37°C for 18–24 hours, and plated on Mueller-Hinton agar [18]. MBC was the lowest concentration yielding no growth. All tests were performed in duplicate with means and standard deviations calculated.

2.11 Statistical analysis

Statistical analysis was performed using SPSS version 22.0. One-way ANOVA followed by a post hoc test (LSD) was employed to assess statistical significance at $p < 0.05$.

2.12 Satisfaction Assessment

The survey test was conducted after approval from the ethics review board with a certificate number COA. No. RSUERB2023-129. A 5-point Likert scale was used to measure satisfaction through 9 questions. Participants received 50 grams of soap samples. They were instructed to use the body soap twice daily. The laundry soap was used for cleaning clothes, surfaces, and equipment by dissolving it in water until cloudy with clay.

3. Results and discussion

3.1 Heavy metal composition in clays

This experiment aimed to assess the levels of heavy metals in selected clay samples used in soap production, including kaolin, white clay, bentonite, and clay loam, to ensure they meet soap production standards. The analysis measured the concentrations of arsenic (As), cadmium (Cd), lead (Pb), and mercury (Hg) using Atomic Absorption Spectroscopy (AAS) version spectrAA 220, with the results summarized in Table 1.

Table 1: Heavy metal analysis of clays (ppm)

Heavy metal	Standard Limit*	Kaolin	White clay	Bentonite	Clay loam
Arsenic (As)	5	1.61	0.29	2.09	1.27
Cadmium (Cd)	3	<0.1	0.08	1.14	1.11
Lead (Pb)	20	12.97	0.37	9.70	15.83
Mercury (Hg)	1	0.10	<0.1	<0.1	<0.1

Note: *Standard limitation based on the Ministry of Public Health (2016) [19] and the Industrial Product Standard (TIS 29-2560) [20]

All four clays exhibited heavy metal concentrations well below the permissible limits set by the Ministry of Public Health (2016) [19] and the Industrial Product Standard (TIS 29-2560) [20]. Arsenic levels ranged from 0.29 ppm in white clay to 2.09 ppm in bentonite, all below the 5 ppm limit. Cadmium is less than 3 ppm across all clays, with bentonite having the highest at 1.14 ppm. Lead content is below the 20 ppm threshold, with kaolin and clay loam showing higher levels at 12.97 ppm and 15.83 ppm, respectively. Mercury concentrations in all analyzed samples were found to be below 0.1 ppm, significantly under the regulatory limit of 1 ppm. These findings confirm that all four clay types are safe for use in the formulation of halal soaps, as their heavy metal contents fall well within the accepted safety standards.

3.2 The formulation of four different soap recipes

The formulation of four different soap recipes, adding 5% clay, kaolin, white clay, bentonite, and clay loam are shown in Figure 1. An unscented base formula without clay was used as a control for comparison. The results in Figure 1 show visual and tactile inspection, of both body soap and laundry soap, showing distinct characteristics based on clay types. It was found that the texture of the soap bars, both with and without clay, remained consistently firm and non-brittle. Body soaps with kaolin and white clay had smooth textures and a cream color, while bentonite provided a grayish hue, and clay loam resulted in a rougher, light brown texture. In contrast, laundry soaps appeared whiter due to their different composition, particularly the use of palm kernel oil as the primary base.

The physical and chemical properties of four halal soap with 5% clay in comparison to a base formula without clay are shown in Table 2. The tests were performed according to the Industrial Product Standard of Thailand (TIS 29-2560) for bar soap, examining characteristics such as texture, pH level, foam volume, foam stability, sliminess, and soap corrosion. The results are summarized in Table 2.

Figure 1: 5% Clay soaps containing different types of clay; (A) body soap (B) laundry soap From left to right: without clay, (kaolin), (white clay), (bentonite), (clay loam)

Table 2: Characteristics of some properties according to the Industrial Product Standard (TIS 29-2560)

Characteristics	**standard**	**Type of Clay**				
		No Clay	**Kaolin**	**White Clay**	**Bentonite**	**Clay loam**
Body soap						
Soap Texture	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle
Foam Volume (mL)	High foam volume	69.67± 0.58^{b}	80.00±0.00^{a}	69.00 ±1.00 ^{b}	76.00 ±1.73^{a}	66.67 ±2.89 ^{b}
Foam Stability (min)	Good foam stability	145.00± 5.00 ^{a}	150.00± 5.00^{a}	120.67± 1.15 ^{b}	140.00± 5.00 ^{a}	113.33± 5.77^{b}
Sliminess	None or minimal	+	+	+	+	+
Soap corrosion (%)	minimal	24.02±0.02^{e}	26.01±0.01^{d}	33.12±0.11^{a}	29.78±0.26^{b}	27.64±0.31^{c}
pH	pH 8 – 10	9.55 ±0.05^{c}	9.80 ±0.01^{a}	9.96±0.01^{b}	9.82±0.03^{a}	9.95 ±0.05^{b}
Total fatty matter (%)	> 76.5	79.51± 0.08^{a}	71.80± 0.20^{b}	72.45± 0.05^{b}	71.75± 0.22^{b}	71.67± 1.11^{b}
Free hydroxide (%)	< 0.05	ND	ND	ND	ND	ND
Insoluble matter in ethanol (%)	< 2.5	0.00±0.00^{e}	4.10±0.10^{a}	3.55±0.15^{c}	3.82±0.08^{b}	3.17±0.06^{d}
Chloride (%)	< 0.80	0.06±0.01^{a}	0.03±0.01^{d}	0.03±0.01^{d}	0.05±0.01^{b}	0.43±0.01^{c}
Laundry soap						
Soap Texture	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle
Foam Volume (mL)	High foam volume	70.00±5.00^{b}	66.67 ±2.89^{b}	90.00 ±5.00^{a}	76.67 ±2.89^{b}	90.00 ±5.00^{a}
Foam Stability (min)	Good foam stability	100.00± 10.00^{b}	110.00± 10.00 ^{b}	95.00± 5.00^{b}	138.33± 7.64^{a}	130.00± 5.00^{a}
sliminess	None or minimal	–	–	–	–	–
Corrosion	minimal	28.42±0.08^{e}	30.33±0.06^{d}	41.43±0.06^{a}	39.62±0.34^{b}	35.97±0.03^{c}
pH	pH 8 – 10	9.94 ±0.04	9.98±0.02	9.96±0.02	9.96±0.05	9.97 ±0.02
Total fatty matter (%)	> 62.0	68.82±0.15^{a}	61.07±0.40^{b}	60.20±0.75^{b}	60.45±0.65^{b}	59.49±1.31^{b}
Unsaponifiable matter	< 0.5	0.08±0.03^{d}	0.22±0.25^{a}	0.05±0.05^{e}	0.20±0.00^{b}	0.10±0.13^{c}
Free hydroxide (%)	< 0.1	ND	ND	ND	ND	ND
Insoluble matter in ethanol (%)	< 2.5	0.00±0.00^{b}	3.97±0.15^{a}	4.30±0.10^{a}	3.90±0.10^{a}	4.00±0.50^{a}

Note: – No slime formation, + Very little slime formation, ++ Moderate slime formation, +++ Significant slime formation, clearly visible
Different superscript letters within a row indicate a significant difference according to LSD post hoc test (p< 0.05) at the 0.05 level.

All clay-based soaps demonstrated notable hardness, abundant foam production, and easy rinsing properties. The pH values for all formulas range from 9.55 to 9.96, complying with the standard requirement of pH 8-10 for bar soaps. Additionally, the percentages of free hydroxide and chloride are within the acceptable limits of the Industrial Product Standard (TIS 29-2560), indicating safe levels for use. When selecting the type of clay for the soap formulation, the researchers chose kaolin-based soaps for both body and laundry applications, based on standard references. Notably, kaolin-based soaps produced the highest foam volume, reaching 80 mL, outperforming the other three formulations. This foam volume exceeded the results of Ngahom et al. (2020), who reported foam volumes of 63.33 and 75.00 mL for volcanic ash soaps [15]. In terms of foam stability, kaolin also showed the best performance, with a stability time of 150 minutes. This aligns with the findings of Iriany et al. (2020) [12], who studied coconut oil based soaps with similar foam stability times. Regarding sliminess, all four body soap formulations showed minimal sliminess, complying with industry standards (TIS 29-2560).

When examining the corrosion rate of soaps, clay-based soaps ranged from 26.01% to 33.12%, while the base formula (without clay) had a corrosion rate of 24.02 ± 0.02%. Kaolin exhibited the lowest corrosion rate at 26.01 ± 0.01%. While this corrosion rate was slightly higher than the 11.30% observed for volcanic ash soap tested by Ngahom et al. (2020) [15], it nonetheless demonstrated good durability. The inclusion of clay tends to reduce hardness and slightly increase corrosion. However, kaolin's foam stability and foam volume make it a superior option for body soaps. Its corrosion rate of 26.01 ± 0.01% also reflects better durability compared to other clay-based formulations.

For laundry soap, kaolin again proved to be an excellent choice, with a foam volume of 66.67 ± 2.89 mL and an acceptable foam stability of 110.00 ± 10.00 minutes, although slightly lower than the foam stability of bentonite. While the corrosion rate for kaolin in laundry soap (30.33 ± 0.06%) was lower than that of other clay formulas, it still outperformed other clay-based formulations. Therefore, kaolin is highly recommended for both body and laundry soaps, offering good performance in terms of foam production and stability, with acceptable corrosion levels.

Additionally, it was observed that all clay-based soaps had total fat and insoluble matter in ethanol levels that did not meet standard values. The total fatty matter content for body soap and laundry soap was 71.80 ± 0.20% and 61.07 ± 0.40%, respectively. These values are slightly lower than the standard (>76.5% and >62%, respectively), yet they still provide good cleansing properties, including foam volume. This discrepancy is due to the increased proportion of clay in the formula, which reduced the initial oil content. On the other hand, the inclusion of clay increased the percentage of insoluble matter in ethanol, exceeding the standard threshold. This aligns with its role as a najis cleansing agent, which was an intentional aspect of the clay soap formulation.

Moreover, an expert satisfaction assessment of four halal body soap formulas revealed that kaolin received the highest average score of 4.78 ± 0.30, followed by white clay at 4.71 ± 0.36, bentonite at 4.60 ± 0.46, and clay loam at 4.40 ± 0.46. As a result, kaolin was selected for further study in halal body soap formulation. Similarly, for laundry soap, kaolin received the highest satisfaction score of 4.67 ± 0.41, followed by white clay at 4.56 ± 0.52, bentonite at 4.53 ± 0.41, and clay loam at 4.49 ± 0.47, leading to its selection for further development in halal laundry soap. Kaolin offers the best balance between foam production, stability, and acceptable corrosion rates, making it the recommended choice for both body cleansing and laundry purposes.

3.3 Optimization of Kaolin Content in Halal Body Soap Formulations

Five new formulations were created, with kaolin content ranging from 10% to 30%. A few drops of fragrance were added to enhance user appeal. The products are shown in Figure 2.

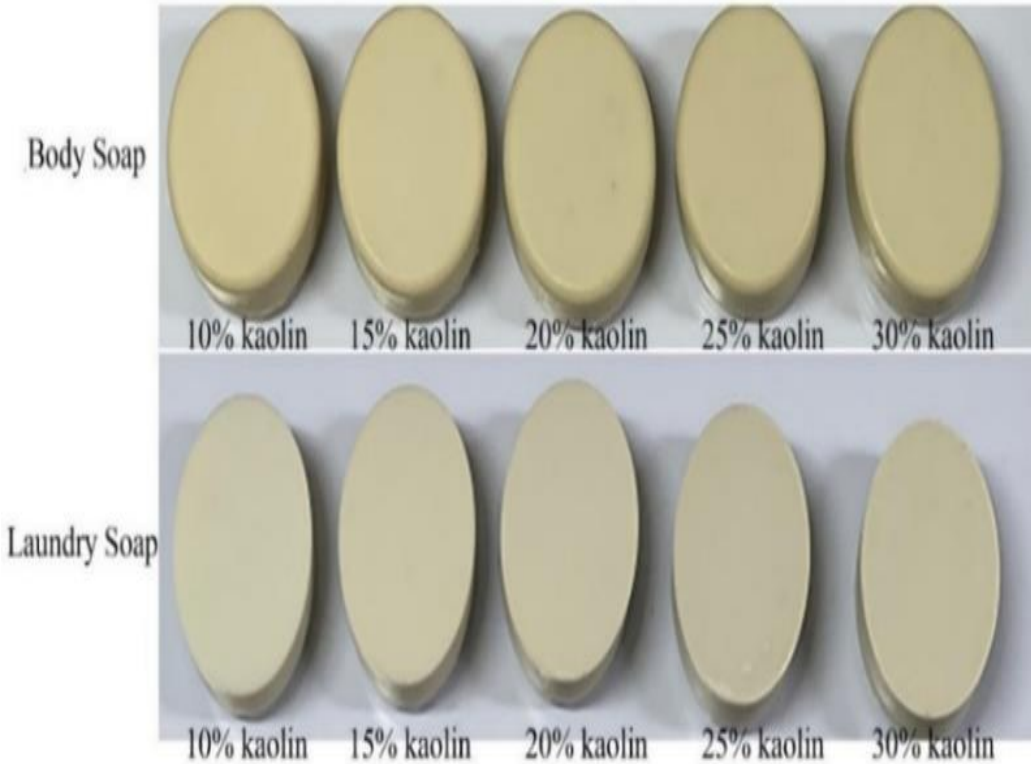

Figure 2: Body and laundry soaps incorporated with various ratios of kaolin

Based on the physical and chemical properties shown in Table 3, the characteristics examined were within the permissible range of the Industrial Product Standard (TIS 28-2550). These include soap texture, pH, free hydroxide, chloride content in body soap, and unsaponifiable matter in laundry soap. None of the formulations exhibited sliminess.

When evaluating user satisfaction factors such as foam volume and stability, kaolin-enriched soaps performed comparably to the standard formula without clay. However, soap corrosion, which affects hardness during use, significantly influences user preference. Increasing clay content tended to decrease soap hardness. A kaolin concentration of 20% was found optimal, resulting in acceptable corrosion rates of 37.00% for body soap and 41.63% for laundry soap. This level provided the best balance between durability and performance, aligning with recommendations from religious experts. Although the total fat content was slightly lower and the amount of non-dissolved matter in ethanol exceeded standard limits, these deviations are considered acceptable for clay-based soaps, which still ensured product safety and user satisfaction. Overall, the inclusion of 20% kaolin improved cleansing performance and met key criteria for both religious and practical use, making it suitable for further development in halal soap formulations.

Table 3: Physical and Chemical properties of clay soaps

Characteristics	standard	% Kaolin				
		(10 %)	(15 %)	(20 %)	(25 %)	(30 %)
Body soap						
Soap Texture	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle
pH	pH 8 – 10	9.98 ±0.03^{a}	9.99 ±0.01^{a}	9.98±0.03^{a}	9.92±0.07^{a}	9.97 ±0.06^{a}
Foam Volume (mL)	High foam volume	76.67 ±2.89^{b}	78.33 ±2.89^{b}	88.33 ±2.89^{a}	78.33 ±2.89^{b}	81.67 ±2.89^{b}
Foam Stability (min)	Good foam stability	147.67± 2.51^{a}	148.33± 2.89^{a}	150.67± 4.04^{a}	147.00± 2.65^{a}	145.33± 4.51^{a}
Sliminess	None or minimal	–	–	–	–	–
Soap Corrosion (%)	minimal	30.76±1.08^{d}	36.24±0.25^{c}	37.00±0.52^{c}	40.57±0.40^{b}	45.50±0.50^{a}
Total fatty matter (%)	> 76.5	64.75±0.31^{a}	63.52±0.47^{a}	51.06±1.05^{b}	41.17±1.12^{c}	35.31±1.01^{d}
Free hydroxide (%)	< 0.05	ND	ND	ND	ND	ND
Insoluble matter in ethanol (%)	< 2.5	9.10±0.10^{a}	12.20±0.10^{b}	13.50±0.10^{c}	18.40±0.10^{d}	19.48±0.51^{e}
Chloride (%)	< 0.80	0.22±0.02^{a}	0.23±0.02 ^{a}	0.34±0.04^{b}	0.41±0.01^{c}	0.43±0.01^{d}
Laundry soap						
	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle	Firm, not brittle
pH	pH 8 – 10	9.75 ±0.05^{a}	9.64 ±0.07^{a}	9.86±0.05^{a}	9.76±0.23^{a}	9.67 ±0.15^{a}
Foam Volume (mL)	High foam volume	79.67 ±0.58^{a}	75.33 ±0.58^{a}	80.00 ±1.00^{a}	81.33 ±3.21^{a}	76.33 ±2.30^{a}
Foam Stability (min)	Good foam stability	147.67± 2.51^{b}	153.00± 2.65^{a}	157.00± 2.65^{a}	160.00± 5.00^{a}	165.00± 5.00^{a}
sliminess	None or minimal	–	–	–	–	–
Corrosion	minimal	31.10±0.85^{e}	35.82±0.28^{d}	41.63±0.33^{c}	39.42±0.07^{b}	44.72±0.24^{a}
Total fatty matter (%)	> 62.0	55.68±0.05^{a}	52.49±0.29^{b}	49.89±0.26^{c}	36.64±0.15^{d}	31.09±0.21^{e}
Unsaponifiable matter	< 0.5	0.40±0.10^{b}	0.27±0.06^{b}	0.23±0.06^{b}	0.45±0.05^{a}	0.48±0.03^{a}
Free hydroxide (%)	< 0.1	ND	ND	ND	ND	ND
Insoluble matter in ethanol (%)	< 2.5	18.03±0.15^{c}	19.10±0.10^{b}	19.50±0.20^{b}	20.70±0.26^{a}	22.85±0.13^{a}

Note: – indicates no slime formation, ND means not detected.

Different superscript letters (a – e), within a row indicate a significant difference at the 0.05 level.

3.4 The Minimum Bactericidal Concentration (MBC)

From Table 4, kaolin alone did not exhibit a measurable minimum bactericidal concentration (MBC) against either *Staphylococcus aureus* (Gram-positive) or *Escherichia coli* (Gram-negative), consistent with the findings of Shehu et al. [21]. This is likely due to insufficient particle-bacteria interaction caused by surface tension [22] and inadequate ion release from unmodified clay [9]. However, when 20% kaolin was incorporated into soaps with pH values above 9, varying degrees of antibacterial effectiveness were observed [23-24]. For

Staphylococcus aureus, the body soap demonstrated superior efficacy with a lower MBC (16 mg/mL) compared to the laundry soap (32 mg/mL). In the case of *Escherichia coli*, both soaps exhibited an MBC of 32 mg/mL, with the laundry soap requiring a higher concentration (>32 mg/mL). These results suggest that kaolin-enriched soap is antibacterial, with greater effectiveness against Gram-positive strains. Significantly, the determination of the minimum inhibitory concentration (MIC) was precluded by the opacity of the soap solution, which obstructed accurate absorbance measurements [25–26].

Table 4: Minimum Bactericidal Concentration of soaps against *Staphylococcus aureus* and *Escherichia* coli

Sample	Staphylococcus aureus		Escherichia coli	
	MBC g/mL ± SD	Results	Results	MBC g/mL ± SD
kaolin	NA			NA
Body soap with kaolin 20 %	16$\pm$0.0			32$\pm$0.0
Laundry soap with kaolin 20 %	>32$\pm$0.0			>32$\pm$0.0

Note: NA indicates not available

3.5 The sensory satisfaction evaluation

The sensory satisfaction evaluation, conducted with a cohort of 66 Muslim participants, yielded high satisfaction scores for 20% kaolin-enrich soap. The body soap garnered superior ratings in cleanliness (4.89 ± 0.35), non-irritation (4.85 ± 0.36), and overall satisfaction (4.85). Correspondingly, the laundry soap achieved peak scores in overall satisfaction (4.91), cleanliness (4.86), and non-irritation (4.80). However, certain aspects of the formulations received comparatively lower ratings such as 1) soap's softness after repeated use (4.65 ± 0.59) and the foam volume (4.55 ± 0.66) was identified as areas for potential improvement. These findings indicate that both soap formulations were well-received by the participants. The results suggest that while the kaolin-containing soaps meet high standards of user satisfaction, there may be scope for further refinement in terms of maintaining softness and foam production to align more closely with user expectations.

3.6 Turbidity of kaolin-based soap solution

This experiment aimed to demonstrate the turbidity of a soap solution mixed with kaolin. A 0.1% w/v soap solution was prepared to reflect typical hand washing conditions, with participants using an average of 0.45 ± 0.26 grams of soap per 500 mL of water. Table 5 compares the turbidity of soap solutions without clay and with 20% kaolin. Results show that the turbidity is approximately 7 times higher for body soap and 30 times higher for laundry soap compared to soap without clay. While no specific turbidity standard exists for najis removal, the increased turbidity demonstrates the effective suspension of clay particles, supporting the use of kaolin soap for ritual cleansing.

Table 5: Turbidity of without clay and with 20% kaolin-enriched soap

	Without Clay	0.1% w/v
Body soap	7.90 ± 0.95	252 ± 22.85
Laundry soap	35.25 ± 3.12	244 ± 8.68

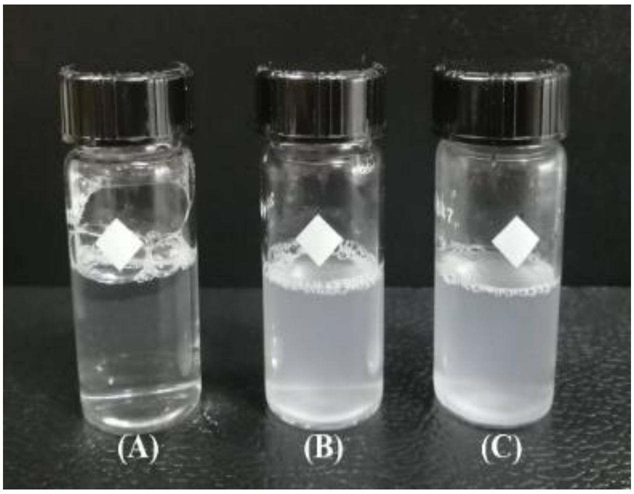

Figure 3: Comparison of turbidity for soap solutions: (A) = 0.1% without clay soap solution, (B) = 0.1% Body soap solution, (C) = 0.1% laundry soap solution.

Figure 3 shows three samples labelled (A), (B), and (C). The visual differences in turbidity among the samples illustrate that both the body soap solution (B) and laundry soap solution (C) are noticeably turbid compared to the sample without clay (A). The observed turbidity in kaolin-enriched soap solutions indicates the effective suspension of clay particles, supporting the potential of clay-based soap as a practical alternative for najis cleansing.

4. Conclusion

This study successfully developed halal soap enriched with clay, specifically designed for cleansing najis (impurities). Kaolin emerged as the preferred clay additive for both body and laundry soaps, as it not only met functional properties but also fulfilled the requirement for the presence of clay particles during use. The 20% kaolin formulation demonstrated suitable pH levels, robust foam production, foam stability, cleanliness, and non-irritation, aligning with industrial safety standards. Turbidity analysis revealed clay particle suspension compared to clay-free soap, directly supporting its mimicry of traditional clay-water. However, the incorporation of clay also presented some challenges, including bar softening and moderate corrosion after use, which affected user satisfaction. Additionally, soap formulations demonstrated effectiveness against *Staphylococcus aureus* compared to *Escherichia coli*.
Further research should assess the soap’s effectiveness in the Sertu process to evaluate the cleansing performance in removing impurities such as dog saliva to ensure its suitability for use within the Muslim community.

5. Conflict of Interest

The authors declare that they have no conflicts of interest

6. Acknowledgements

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