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Research Article

Antibacterial Activity of Solid Soap from Turmeric Rhizome Water Extract *(Curcuma domestica)* against *Staphylococcus aureus*

Aktivitas Antibakteri Sabun Padat dari Ekstrak Air Rimpang Kunyit (Curcuma domestica) terhadap Staphylococcus aureus

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ABSTRACT

Turmeric (*Curcuma domestica*) contains flavonoids and curcumin, which exhibit antibacterial properties, making it a suitable active ingredient for solid soap production. Solid soap must pass physical, chemical, and antibacterial activity assessments to ensure quality. This study evaluates the physical, chemical, and antibacterial properties of turmeric rhizome water extract-based solid soap against *Staphylococcus aureus*. The research was conducted experimentally, using turmeric rhizome water extract obtained through the maceration method. Antibacterial activity was assessed using the well diffusion method. The solid soap was formulated through saponification, incorporating thick extract (F1) and liquid extract (F2) of turmeric rhizome as active ingredients. Findings indicate that soap F1 has a solid texture, odourless, brown, and homogeneous, with a foam height of 13.63 cm±0.35, a moisture content of 7.52%±0.37, a pH of 10.03±0.05, a free alkali of 0.094%±0.008, and an inhibition zone diameter of 22.38 mm±0.58, classified as very strong antibacterial. Soap formulated F2 demonstrated comparable characteristics, with an 18.60 mm±0.96 inhibition zone, categorised as strong antibacterial. The soap F1 complies with pharmaceutical standards and effectively inhibits *Staphylococcus aureus* growth.

Keywords: Antibacterial Activity, Turmeric Rhizome Water Extract, Solid Soap

ABSTRAK

Kunyit (Curcuma domestica) mengandung flavonoid dan kurkumin yang memiliki aktivitas antibakteri, sehingga dapat digunakan sebagai bahan aktif dalam pembuatan sabun padat. Sabun padat harus memenuhi standar mutu fisik, kimia, dan aktivitas antibakteri agar dapat digunakan dengan baik. Penelitian ini bertujuan untuk mengevaluasi mutu fisik, kimia, dan aktivitas antibakteri sabun padat ekstrak air rimpang kunyit terhadap Staphylococcus aureus. Penelitian dilakukan secara eksperimental dengan pembuatan ekstrak air rimpang kunyit menggunakan metode maserasi dan diuji aktivitas antibakterinya menggunakan metode sumuran. Sabun padat dibuatkan dengan metode saponifikasi dengan bahan aktif ekstrak kental rimpang kunyit (F1) dan ekstrak cair rimpang kunyit (F2). Hasil penelitian menunjukkan bahwa sabun F1 memiliki tekstur padat, tidak berbau, berwarna cokelat,

homogen, dengan tinggi busa 13,63 cm±0,35, kadar air 7,52%±0,37, pH 10,03±0,05, alkali bebas 0,094%±0,008, dan diameter zona hambat 22,38 mm±0,58 yang termasuk kategori antibakteri sangat kuat. Sabun F2 menunjukkan hasil serupa, namun zona hambatnya 18,60 mm±0,96 dan termasuk kategori antibakteri kuat. Sabun F1 memenuhi persyaratan farmasetika dan efektif menghambat pertumbuhan Staphylococcus aureus.

Kata Kunci: *Aktivitas Antibakteri, Ekstrak Air Rimpang Kunyit, Sabun Padat*

INTRODUCTION

Soap is a cleaning material, obtained from a saponification reaction between fatty acids and a base. The fatty acids used to make soap can be derived from either animals or plants. The saponification reaction not only produces soap, but also glycerol (1,2). The fatty acids used are olive oil, coconut oil, and palm oil. Coconut oil is a foaming agent and contains lauric acid, which has antibacterial and antioxidant properties. Palm oil plays a role in hardening solid soap and produces a stable foam, whereas olive oil functions to moisturise the skin (3,4). The base used in soap making is Sodium Hydroxide (NaOH), the amount of which must be in accordance with the Saponification Value (SV). Besides the main ingredients, solid soap can also be given additional ingredients that aim to provide more value to the solid soap product. These extra ingredients are, for example, colourants, fragrances, and active substances (5). Additional ingredients can originate from synthetic and natural sources (6)

Turmeric rhizome is one of the natural ingredients that can be used as an additional ingredient in making solid soap. Besides being a colourant, turmeric also functions as an active substance because it contains curcumin and flavonoids. Curcumin can inhibit the activity of several essential enzymes in bacterial metabolism, whereas flavonoids can damage the bacterial cell wall (7,8). The research by Pratiwi *et al*., (2022) mentions that flavonoids in turmeric rhizome have antibacterial activity against *Staphylococcus aureus* (9). This bacterium is widely found on the human body's skin (10). Curcumin and flavonoids are secondary metabolites that are polar in nature. Curcumin has a melting point of 183°C, and its structure will be damaged if it receives heating above its melting point (11), whereas flavonoids tend to experience structural damage at temperatures above 50°C (12).

In the production of herbal soap, the natural material used is generally in the form of an extract, either a thick or a liquid extract. Extraction is carried out by considering the properties of the secondary metabolites that will be taken from the said natural material. These properties determine the extraction method and the solvent to be used. Curcumin is relatively resistant to heating, whereas flavonoids are not. Therefore, to extract both of them, a cold method is used. Maceration is one of the cold extraction methods that does not require specialised equipment and does not require a large amount of solvent. Curcumin and flavonoids are polar in nature, so a polar solvent is used for their extraction, adhering to the 'like dissolves like' principle. The active substances that can be drawn out by water include curcumin, saponins, alkaloids, flavonoids, and tannins (13).

Although turmeric rhizome contains curcumin and flavonoids with proven antibacterial properties, limited studies have explored the incorporation of its water extract into solid soap formulations and evaluated its quality and antibacterial activity against *Staphylococcus aureus.* A solid soap preparation was produced with the addition of a water extract from the turmeric rhizome. The water extract of turmeric rhizome is used, making its production process easier to implement in the community. The water extract of turmeric rhizome is divided into two treatments: one with and one without evaporation. This treatment aims to determine whether both extracts have antibacterial activity against *Staphylococcus aureus*. Physical and chemical quality test were conducted to determine whether the resulting solid soap meets the established quality standards. Therefore, this study was conducted to

formulate solid soap with turmeric rhizome water extract and to evaluate its physical, chemical, and antibacterial properties against *Staphylococcus aureus*.

MATERIALS AND METHODS

Materials

The materials used were fresh turmeric rhizomes, which were obtained from Materia Medica in Batu City. The determination process was carried out at Materia Medica Batu with letter number 000.9.3/7579/102.20/2024. Coconut oil (Barco, PT. Barco), olive oil (King Zaitun Pomace, CV. Syifa Herbal Alami), palm oil (Bimoli Klasik, PT. Salim Ivomas Pratama Tbk.), aquadest, Mannitol Salt Agar (MSA) medium, *Staphylococcus aureus* culture, Phenolphthalein (PP) indicator, Methyl Red (MM) indicator, sodium tetraborate, Magnesium (Mg) powder, Hydrochloric Acid ($HCl_{(p)}$), 0.1 N HCl, technical-grade NaOH, 5% NaOH, Potassium Hydroxide (KOH), and 96% ethanol.

Methods

The method used in this research was the well-diffusion method, using MSA medium. The test was carried out on the bacterium *Staphylococcus aureus.*

Preparation of Turmeric Rhizome Water Extract

200 grams of fresh turmeric rhizome were prepared and weighed, then pureed using a blender. Subsequently, 1,400 millilitres (mL) of water was added (1:7). The mixture was then macerated for 3 days, with occasional stirring performed. The extraction result was filtered, separated into the filtrate and the residue, and then the filtrate result was divided into two parts. The first part of the turmeric rhizome water filtrate was evaporated using a water bath at a temperature of below 50°C until its volume was reduced to half, whereas the second part was not evaporated and placed into the refrigerator (3).

Phytochemical Screening

Flavonoid

The flavonoid test was carried out by adding 0.2 grams of Mg powder and 1 mL of $HCl_{(p)}$ to the turmeric rhizome water extract. The reaction result was observed; if a red, yellow, or orange colour formed, it indicated the presence of flavonoid content (14).

Curcumin

The curcumin test was carried out by heating 0.2 grams of the turmeric rhizome water extract over a bunsen flame. Then, 3 drops of 5% NaOH were added. The reaction result was observed; if a yellow or red colour formed, it indicated the presence of curcumin content (14).

Preparation of Solid Soap with Turmeric Rhizome Water Extract

The solid soap was made with two formulae, F1 and F2. In F1, the active ingredient used was the concentrated turmeric rhizome water extract, whereas for F2, the unconcentrated turmeric rhizome water extract was used. 66 grams of coconut oil, 33 grams of palm oil, and 93 grams of olive oil were weighed. 29.1 grams of technical grade NaOH was weighed; the concentrated (thick extract) and unconcentrated (liquid extract) turmeric rhizome water extracts were each weighed for a total of 78.9 grams. In the preparation of F1, the turmeric rhizome water extract was placed into a beaker glass. NaOH was added little by little until it was dissolved, then left to stand for several minutes until the NaOH solution reached a temperature below 50°C. The NaOH solution mixed with the extract was added to the oil mixture and stirred rapidly until trace was achieved. The resulting mixture was then poured into a mould and allowed to cure for 7 days to 1 month, during which the saponification process continued and residual free alkali remained. The same procedure was applied to F2, followed by antibacterial activity testing and characterisation of the soap for each formula (15).

Physical Quality Testing
Organoleptic Test

The observations were made on the colour, texture, and odour of the solid soap. The observation results were recorded (16).

Homogeneity Test

The solid soap was thinly sliced and placed on a transparent glass slide. Then, the presence of particulate granules in the solid soap was observed, and the observation results were recorded (16).

Foam Height Test

1 grams of solid soap was placed into a test tube, and 10 mL of aquadest was added. The test tube was shaken until foam was produced, followed by shaking using a vortex for 1 minute. The foam height was observed for 5 minutes, and the foam height result was recorded (16).

Water Content Test

The bottle, which had been dried in an oven at 105°C for 30 minutes, was weighed. A total of 1.25 grams of the solid soap sample was placed in the weighing bottle, then heated in an oven at 105°C for 1 hour. After that, it was cooled in a desiccator to room temperature and then weighed. The heating and weighing procedure was repeated until a constant weight was obtained (17).

Chemical Quality Testing
pH Test

1 grams of the solid soap sample was weighed and placed into a beaker containing 10 mL of aquadest. The solution was left for 1 hour, with several stirrings occurring during this time. Subsequently, a pH measurement of the solid soap was performed using a pH metre (Senz pH, Scientific), then the measurement was observed, and the result was recorded (17).

Free Alkali Test

It was started with the preparation of neutral ethanol with 1 litre (L) of 96% ethanol, to which were added five drops of PP indicator, and was titrated with 0.1 N KOH drop by drop until the solution turned a pink colour (18). Subsequently, 1.25 grams of solid soap was dissolved in 50 mL of neutral ethanol in an erlenmeyer flask, then a condenser was fitted for reflux. The sample in the erlenmeyer flask was heated on a water bath for 30 minutes, then after the solid soap was completely dissolved, the liquid was filtered using filter paper into another erlenmeyer flask, and the filtrate was stored (15,17).

Standardisation of the standard HCl solution was carried out using a secondary standard solution of sodium tetraborate (19). A total of 0.1 grams of sodium tetraborate was weighed, then dissolved in a sample pot and was transferred into a 50 mL volumetric flask. After that, aquadest was added to the neck of the volumetric flask, shaken, then aquadest was added again up to the mark, and was homogenised. 5 mL of the sodium tetraborate solution was taken using a volumetric pipette, placed into an erlenmeyer flask, and then 2-3 drops of MM indicator were added. Subsequently, a titration process was carried out using 0.1 N HCl solution until the yellow or red colour changed to pink, with a titration volume difference of no more than 0.1 mL and the titration volume was recorded. After obtaining the filtrate from the previous step, it was heated until almost boiling, and then 2-3 drops of 1% PP were added. If the solution was alkaline, which was indicated by a red colour change, then a titration was carried out using the standard 0.1 N HCl solution until the red colour just disappeared. The titration result was calculated as the NaOH content in the sample. The percentage of free alkali was calculated using the following formula:

$$\text{Free Alkali} = \frac{40 \times V \times N}{M} \times 100\%$$

Description:
40 = Molecular Weight (MW) of NaOH
V = Volume of HCl used (mL)
N = Normality of HCl used
M = Weight of sample (mg)

Antibacterial Activity Testing

27 grams of MSA medium were weighed, placed into an erlenmeyer flask, dissolved with 250 mL of aquadest, and heated using a bunsen burner flame whilst being stirred until homogeneous. The erlenmeyer flask was plugged with cotton and wrapped using brown paper to be sterilised in an autoclave at a temperature of 121°C for 15 minutes. 1 mL of the bacterial suspension was placed into a petri dish, the MSA medium was poured into the petri dish containing the bacterial suspension, then it was homogenised by means of being swirled in a figure-of-eight motion, and was left until solidified. The solidified medium was bored using a cork borer. 1 mL of the solid soap with turmeric rhizome water extract solution was placed into the well of the petri dish; this process was carried out inside a laminar airflow (Mascotte Model LH-S). The solid soap solution was made by dissolving 5 grams of the soap in 10 mL of sterile aquadest so that there was no contamination. The petri dish was sealed using brown paper and was incubated for 1x24 hours at a temperature of 37°C; the zone of inhibition around the well was observed and measured using a vernier calliper (20,21).

Data Analysis

The evaluation results of the physical quality, chemical quality, and antibacterial activity tests of the solid soap preparation with turmeric rhizome water extract were statistically analysed using the *Two-Way ANOVA* test, GraphPad version 10.

RESULTS

Extraction

The turmeric rhizome used was the species *Curcuma longa* L. with the synonym *Curcuma domestica* Val. The extraction of the turmeric rhizome was carried out using the maceration method in a refrigerator to avoid microbial growth. From this process, a turmeric rhizome water extract was obtained in the amount of 1,264 mL. This extract was divided into two parts. In part 1, the extract was subjected to concentration, which was subsequently used as the active ingredient in F1, whereas in part 2, the extract was not subjected to concentration and was used as the active ingredient in F2. The characteristics of the extract produced for F1 had a thicker consistency compared to F2. In addition, the F1 extract had a blackish-brown colour, which appeared darker compared to F2 which was brown in colour. This may have occurred due to the concentration process, resulting in a darker colour being produced in the concentrated turmeric rhizome water extract. A comparison of the results of the concentrated and unconcentrated turmeric rhizome water extract is shown in **Table 1**.

Table 1. Result of the Concentrated and Unconcentrated Turmeric Rhizome Water Extract

Formula	Result of Turmeric Rhizome Water Extract (mL)	Requirement of Turmeric Rhizome Water Extract for Solid Soap Preparation (grams)
F1	316	78.9
F2	632	78.9

Phytochemical Screening for Flavonoid and Curcumin Compounds

Table 2. Test Result of the Phytochemical Screening for Flavonoid and Curcumin in the Concentrated and Unconcentrated Turmeric Rhizome Water Extract

Test	Reagent	Results	
		Concentrated Turmeric Rhizome Water Extract	Unconcentrated Turmeric Rhizome Water Extract
Flavonoid	Mg Powder + $HCl_{(p)}$	++	+
Curcumin	NaOH Solution	++	+

Description:
(++) = Higher intensity of secondary metabolite compound content
(+) = Lower intensity of secondary metabolite compound content

The phytochemical screening test for flavonoids and curcumin compounds was qualitatively carried out on both the concentrated and unconcentrated turmeric rhizome water extracts. Based on

Table 2, the concentrated and unconcentrated turmeric rhizome water extracts showed positive results for the testing of flavonoid and curcumin compounds. However, the concentrated turmeric rhizome water extract showed a more intense colour intensity compared to the unconcentrated turmeric rhizome water extract. This colour intensity indicates the amount of these compounds within the extract. The concentration process greatly influences the identification results, as the thicker the extract, the higher the levels of curcumin and flavonoid contained within it (22,23).

Evaluation of Physical and Chemical Quality

The research results showed that the physical quality evaluation of the solid soap with turmeric rhizome water extract, for both F1 and F2, met the requirements. Based on **Figure 1**, the organoleptic test results of both formulae satisfy the requirements, as the soap did not experience changes in colour, texture, and odour. In the homogeneity test, F1 and F2 showed that no coarse granules were present, indicating that the soap was homogeneous, as shown in **Table 3**. Additionally, the foam height and free alkali tests showed that the F1 and F2 solid soaps complied with the requirements. Based on **Table 3**, the foam height of both soap formulae had an average value of more than 9.5 cm after 5 minutes, whereas the water content obtained did not exceed 23%.

(F1) (F2)

Figure 1. Results of the preparation of solid soap with concentrated turmeric rhizome water extract (F1) and solid soap with unconcentrated turmeric rhizome water extract (F2)

The research results showed that in the chemical quality evaluation, both formulae of the solid soap with turmeric rhizome water extract met the requirements. Based on **Table 3**, the pH test results for F1 and F2 ranged between 6 to 11. Meanwhile, the free alkali test results for F1 and F2 did not exceed 0.1%.

Table 3. Comparison of the Test Results of the Physical and Chemical Quality of the Solid Soap with Turmeric Rhizome Water Extract against the Standard

Quality	Test	Formula	Results
Physical	Organoleptic	F1	Brown colour, solid texture, odourless
		F2	Cream colour, solid texture, odourless
	Homogeneity	F1	Homogeneous (no coarse granules present)
		F2	Homogeneous (no coarse granules present)
	Foam Height	F1	13.63 cm±0.35*
		F2	12.20 cm±0.62
	Water Content	F1	7.51%±0.37**
		F2	9.17%±1.71
Chemical	pH	F1	10.03 ± 0.05^{ns}
		F2	10.00±0
	Free Alkali	F1	$0.09\%\pm0.008^{ns}$
		F2	0.09%±0.0001

Description:
(*) : $p<0.05$
(**) : $p<0.01$
(^{ns}) : Not significant ($p>0.05$)

Antibacterial Activity

The antibacterial testing of the solid soap preparation with turmeric rhizome water extract against *Staphylococcus aureus* was conducted to assess the maximum effectiveness of the solid soap as an antibacterial agent when combined with the active ingredient, turmeric rhizome extract. The comparison of inhibition zone diameters is shown in **Figure 2**. The test results against *Staphylococcus aureus* for F1 showed an average inhibition zone diameter of 22.38±0.58 mm, which within the very strong category. For F2, an average zone of inhibition diameter of 18.60±0.96 mm was obtained, which falls within the strong category. This result indicate that both formulae have antibacterial activity against *Staphylococcus aureus*.

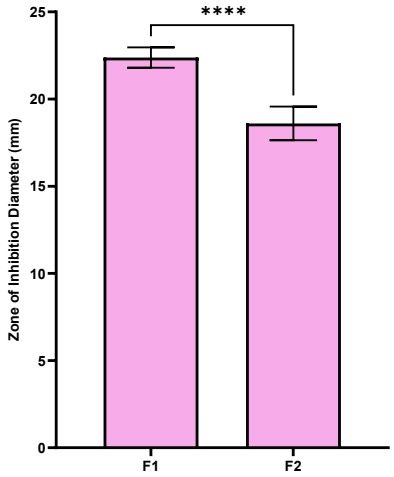

Figure 2. Graph of the zone of inhibition diameter of the solid soap with concentrated turmeric rhizome water extract (F1) and the solid soap with unconcentrated turmeric rhizome water extract (F2) against *Staphylococcus aureus* (**** = p<0.0001)

DISCUSSION

The phytochemical screening test was carried out to determine the presence of flavonoid and curcumin compounds because these secondary metabolites play a role as antibacterial agents (24). Flavonoids can damage the bacterial cell wall, denature bacterial cell proteins, which ultimately leads to bacterial death. Additionally, curcumin inhibits the activity of several essential enzymes in bacterial metabolism, including DNA gyrase and RNA polymerase. These enzymes play an important role in the replication and transcription of bacterial DNA, so their inhibition can suppress bacterial growth (8). The research results indicate that the use of a water solvent in the extraction process can extract the secondary metabolites flavonoids and curcumin that are present in turmeric rhizome.

The physical quality evaluation of the solid soap preparation in this research included organoleptic, homogeneity, foam height, and water content. The organoleptic test was carried out visually using the senses to observe the colour, texture, and odour of the solid soap with turmeric rhizome water extract. The colour of the solid soap followed the colour produced by the extract due to the presence of curcumin, which naturally provides a yellow colour (25). In this research, the F1 solid soap displayed a brown colour, whereas the F2 solid soap had a cream colour. This colour difference was influenced by the use of the turmeric rhizome water extract, where F1 used the active ingredient of the concentrated turmeric rhizome water extract, and F2 used the unconcentrated turmeric rhizome water extract. Although the amount of extract used was the same, the presence of a concentration treatment can increased the intensity of the colour produced in the solid soap. The higher the concentration of the extract added, the darker the colour produced (26). The soap produced from both formulae had a solid texture, but was not too hard, because the concentration of palm oil used was only 11%. Palm oil is an oil that contains a high amount of palmitic acid ($C_{16}H_{32}O_2$), namely as much as 44.3%. The function of this palmitic acid is to make the soap hard and maintain foam stability (3). The use of coconut oil, with its lauric acid ($C_{12}H_{24}O_2$) content, also provides provide good foaming properties

and natural antimicrobial properties (27). The use of olive oil with its oleic acid ($C_{18}H_{34}O_2$) content also helps to prevent dry and scaly skin (4).

The homogeneity test of the solid soap was conducted visually using the senses. A solid soap of good quality is indicated by ingredients that are evenly dispersed with one another, so that each part of the solid soap contains the same amount of efficacy. Homogeneity is greatly influenced by the stirring process, particularly the consistency of the stirring method. A potential issue that can arise during the stirring process is the agglomeration of the extract, which may then precipitate to the bottom of the container. In accordance with the research by Shantia *et al.,* (14), the duration of stirring will affect homogeneity, because a long stirring time will expand the contact area along with the increasing stirring speed, which will increase the homogeneity of a mixture. This is similar to the mixing of oil and water phases, which requires consistent stirring so that the two phases can unite. A solid soap is said to be homogeneous if there are no coarse granules (16). In this homogeneity test, the results obtained for F1 and F2 indicate homogeneous visual properties, with no coarse granules present.

Foam is a form of colloid, in which the dispersed phase is a gas, generally air or Carbon Dioxide (CO_2), and the dispersing medium is a liquid. The foam stability produced by solid soap is obtained from the presence of a surfactant. The surfactant itself is composed of hydrophilic and hydrophobic groups, in which the hydrophilic group binds to water molecules, whereas the hydrophobic group moves towards the surface of the solution facing the air. When the water and surfactant solution meet, air is then passed through it, and simultaneously air bubbles emerge from within the liquid, coated with a thin layer of liquid containing the surfactant, forming foam (28). The foam produced by the solid soap is one of the attractions of the said product. The ability of bubbles to maintain their size and elasticity in a thin layer is referred to as foam stability. One method of quality control for solid soap, so that it has the appropriate ability to produce and maintain foam stability, is the foam height test. The higher the foam stability result, the better the quality of the foam produced (29). The requirement for the foam height produced is >9.5 cm and stable for 5 minutes (30). Based on **Table 3**, this difference in foam height may be attributed to the use of concentrated and unconcentrated extracts. Although the amount of extract used was the same, the presence of the concentration treatment resulted in F1 having a lower water content than F2 in the solid soap formulation. The results of the *Two-Way ANOVA* statistical analysis show a significance value of 0.0204 ($p<0.05$), indicating a significant difference in foam height between F1 and F2.

The water content in solid soap is one of the assessment parameters for the product's shelf life. A high water content in solid soap will more easily experience weight loss when the solid soap is used (31), whereas a low water content can increase the shelf life of the solid soap. The water content test was carried out using the principle of heating at 105°C for 1 hour. The permitted water content requirement is a maximum of 23% (17). **Table 3** shows that the use of the extract affects the difference in water content results between the two formulae. The presence of a concentration treatment causes F1 to have a lower water content than F2 in the solid soap produced, even though the same amount of extract was used. The results of the statistical analysis using the *Two-Way ANOVA* show a significance value of 0.0084 ($p<0.01$), indicating a significant difference in water content between F1 and F2.

The degree of acidity, or what is commonly known as pH, is a standard to state the level of acidity or basicity of a solid soap. A pH value is said to be neutral if it has a value of 7, whereas a pH <7 indicates an acidic nature, and a pH >7 indicates a alkaline nature. The highest value for the degree of acidity is 0, and the highest value for the degree of alkalinity is 14 (32). One of the feasibility parameters for solid soap is its pH. An unsuitable pH value of a solid soap will affect the skin's pH. Soap with a very acidic pH can damage the skin's natural acid mantle, which can block reactions between the skin and bacteria and viruses, whereas a very alkaline pH can remove the skin's moisture, thereby potentially causing dry skin, irritation, and allergies (33). A factor that can influence the high and low pH values of a solid soap is the saponification process, specifically in the hydrolysis reaction. This can be overcome by the addition of excess fat or oil, although it can reduce the hardness of the solid soap (34,35). The appropriate pH range for solid soap is between 6-11 (17). Based on **Table 3**, this difference in pH value is influenced by the use of the concentrated and unconcentrated turmeric rhizome water extract; even though the amount of extract used was the same, the presence of a concentration treatment will increase the concentration of the extract, thereby also increasing the level of alkalinity of the solid soap. The results of the statistical analysis using *Two-Way ANOVA* show a significance value of 0.9539 ($p>0.05$). This indicates that there is no significant difference in pH between F1 and F2.

An excess of alkali content can cause negative effects for users of the solid soap, such as making the skin dry, causing it to feel scaly and potentially peel, and creating a place for bacteria to grow. Free alkali is an alkali that is contained in solid soap, but is not bound as a compound. This excess of alkali can occur as a result of excessive alkali addition during the solid soap-making process (15). The free alkali content in solid soap is a maximum of 0.1% (17). The free alkali content was determined by titration using a standard acid. The solid soap-making process should utilise balanced fatty acids and bases, ensuring that the solid soap does not contain excessive amounts of free fatty acids or free alkali. The free alkali content values for F1 and F2 indicate that the soap remains safe to use and complies with the standard, specifically not exceeding 0.1%. The results of the statistical analysis using *Two-Way ANOVA* show a significance value of >0.9999 ($p>0.05$), indicating that there is no significant difference in free alkali content between F1 and F2 soap.

Antibacterial activity testing was carried out on both formulas, namely F1 and F2. Based on **Table 3**, F1 and F2 were able to inhibit the growth of the bacterium *Staphylococcus aureus*, which was indicated by the presence of a clear zone around the well. The clear zone that formed is a zone of inhibition against bacterial growth produced by the sample. The categories for the bacterial growth inhibition zone are classified as follows: ≤5 mm (weak); 5-10 mm (moderate); 10-20 mm (strong); and ≥20 mm (very strong) (36). F1 solid soap showed a result of very strong antibacterial activity, because the concentration of secondary metabolite compounds such as curcumin and flavonoid was higher compared to F2. This is also supported by the data in **Table 1**, which shows that the higher the concentration of the active compound, the greater the potential to inhibit bacterial growth (24). F2 solid soap exhibited strong activity, although not as pronounced as F1. The difference in the inhibition zone for F1 and F2 can be influenced by the extract that was added to the sample. The turmeric rhizome water extract contains active compounds that provide an antibacterial effect through various mechanisms. Flavonoid compounds can kill bacteria by lysing the bacterial cell wall and lowering the bacterial cell density (37). In addition, solid soap without the addition of an extract tends to have a basic pH. This can function as an antibacterial agent, because bacteria cannot live at a pH that is too acidic or too basic. Bacteria grow in pH conditions close to neutral (38). The results of the *Two-Way ANOVA* analysis show a significance value of <0.0001 ($p<0.0001$), indicating a significant difference in antibacterial activity between F1 (very strong category) and F2 (strong category).

CONCLUSION

The physical and chemical properties of the F1 and F2 solid soaps meet the standards. The antibacterial activity against *Staphylococcus aureus* for F1 belongs to the very strong category, whereas F2 belongs to the strong category. Based on the results obtained, the extract evaporation process affects the antibacterial activity of the solid soap. To improve the quality of the solid soap, testing needs to be carried out on other supporting parameters, such as a moisturising effectiveness test.

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