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Vegetable Oil and *Hibiscus rosa-sinensis* Leaf Extract in Solid Soap Formulations

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Abstract
This study identifies the effects of vegetable oil formulation and *Hibiscus rosa-sinensis* leaf extract concentration on the physicochemical quality of laboratory-scale solid soaps. A 3 x 4 factorial design is used, consisting of three oil-based ingredients (A1, A2, and A3) made from coconut, olive, and palm oil and four extracts (0, 1, 2, and 3%). The parameters measured are pH, moisture content, foam height, foam stability, organoleptic acceptance, and the maximum UV-Vis wavelength of soaps containing certain extracts. The pH of all samples ranged from 9.00 to 9.43, indicating a soap-alkaline system consistent with saponification. The moisture content varies from 11.00 to 19.00%; some samples meet the 15% humidity criteria, while F1 and F4 exceed it. The stability of the foam ranges from 74.96 to 88.89%, and the height of the foam ranges from 0.33 to 1.33 cm. A3 oil base showed the lowest average moisture content (12.33%) and the highest average foam stability (84.77%). Organoleptic evaluation showed that F5 was the most preferred sample, while F11 was chosen as the strongest technical candidate because it contains 2% extract, has the lowest moisture content, and exhibits the highest foam stability. UV-Vis analysis of soap containing A3 extract showed a lambda max value of 374-377 nm with an absorbance value of 0.747-0.751, supporting the persistence of flavonoid-related absorption in the soap matrix. The findings suggest that the composition of vegetable oil and the concentration of H. rosa-sinensis leaf extract affect the quality of solid soap and should be optimized together.

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INTRODUCTION

Solid soap remains an important cleansing product because it is applied directly to the skin and is closely related to comfort, safety, and consumer acceptance. Chemically, soap is produced by the hydrolysis of alkaline triglycerides, in which fatty acids from oils or fats react with sodium hydroxide to form salts of sodium fatty acids and glycerol. The resulting amphiphilic molecules reduce the tension of the interface and help the dispersion of oily impurities in the water.

As the cosmetics industry develops, the use of synthetic soaps is increasing because it is practical and economical. However, synthetic soaps generally contain surfactants such as Sodium Lauryl Sulfate (SLS) which have the potential to have a negative impact on skin health. Research shows that exposure to SLS concentrations of 1–2% can cause skin moisture loss, decrease hydration, damage skin barrier function, and increase the risk of irritation, especially in sensitive skin (Hanistya, 2020; Rosa, 2024). In addition to having an impact on health, synthetic surfactants that are discarded into the environment can also reduce the quality of waters, interfere with the growth of microorganisms, and have negative effects on aquatic organisms. Therefore, the development of natural soaps that are safer for the skin, environmentally friendly, and easily degradable is an important alternative to be developed (Wahyudi, 2022).

One approach that can be taken to overcome this problem is to optimize the composition of vegetable oil through a combination of coconut oil, palm oil, and olive oil, then combine it with *Hibiscus rosa-sinensis* leaf extract at several concentration levels. This approach is expected to be able to produce solid soap formulations with better physicochemical characteristics while maintaining bioactive compounds derived from plant extracts (Arifina, 2024).

Vegetable oils are relevant raw materials for sustainable soap production because they are renewable, biodegradable, and contain fatty acid profiles that can be adjusted to obtain specific properties. Coconut oil is generally associated with its cleansing and foaming ability due to its short-chain saturated fatty acids, while olive oil contributes emollient characteristics through its oleic-rich fraction. Palm oil can support stem structure and hardness. Recent studies have shown that the properties of natural bar soap are highly dependent on the oil matrix, filler or additive type, and compliance with national quality requirements (Sukeksi et al., 2021; Aisy et al., 2022). Cleaner vegetable oil saponification has also been highlighted as a promising route to developing low-impact cleaning products (Stanescu et al., 2025).

Plant extracts are increasingly incorporated into soaps to provide functional and sensory value. Studies of applied soap formulations have shown that *Hibiscus rosa-sinensis* extract can be used in soap-related laboratory work, while other botanical extracts can affect the physicochemical and organoleptic qualities in vegetable oil-based soap systems (Ahmadi & Maripa, 2022; Maripa & Ahmadi, 2023). *Hibiscus rosa-sinensis* L. is a medicinal and ornamental species that contains flavonoids, phenolic compounds, tannins, and saponins. These secondary metabolites are relevant to soap development because they can contribute to the antioxidant potential, natural color, sensory properties, and behaviors of foam. The presence of flavonoids and phenolics also justifies the use of UV-Vis spectrophotometry as these compounds generally absorb light in ultraviolet-visible areas.

Previous research has discussed solid soaps made from vegetable oils or soaps enriched with plant extracts. The context of soap and household products has also been used in chemistry education and vocational industry settings to link raw materials, procedures, product quality evaluation, and workplace practices (Ahmadi & Maripa, 2022; Ahmadi & Maripa, 2026; Maripa & Ahmadi, 2023). However, simultaneous comparisons of the three coconut-olive-palm oil bases with stratified H. rosa-sinensis leaf extracts remained limited, especially when pH, humidity, foam height, foam stability, organoleptic response, and UV-Vis characteristics were interpreted together. Therefore, this study aims to identify the effect of vegetable oil formulation and the concentration of H. rosa-sinensis leaf extract on the physicochemical quality of solid soap.

This research is important because of the increasing need for natural soap products that not only function as cleaners, but also have added value from the content of plant bioactive compounds. On the other hand, different formulations of vegetable oils can produce different soap characteristics so that the right formulation is needed to obtain products with moisture content, pH, foam stability, and physicochemical quality that meets standards. Therefore, the identification of the combination of vegetable oil and *Hibiscus rosa-sinensis* extract concentration is needed as the basis for the development of natural solid soap that is of higher quality, safety, and has the potential to be developed as an economically valuable product.

METHOD

Research design

This laboratory experiment uses a 3 x 4 factorial design. The first factor is the formulation of vegetable oils, which consists of A1, A2, and A3, while the second factor is the concentration of H. rosa-sinensis leaf extract, which consists of V0, V1, V2, and V3. This combination results in 12 soap samples. Each formulation is prepared once, and each physicochemical parameter is measured three times on the same sample to improve the measurement precision. The work is designed to be carried out at the Chemistry Laboratory, Faculty of Science, Engineering, and Applied Sciences, Mandalika University of Education, Mataram, Indonesia.

The main ingredients are coconut oil, olive oil, palm oil, sodium hydroxide, distilled water, fresh H. rosa-sinensis leaves, 70% ethanol, and fragrances. Such instruments include digital scales, glassware, blenders, ovens, hot plates, thermometers, soap molds, pH meters or pH paper, UV-Vis spectrophotometers, cuvettes, and pipettes.

Soap extraction and preparation

Fresh H. rosa-sinensis leaves are washed, air-dried or dried in an oven at low temperatures, and ground into simplicia powder. A total of 29 g of leaf powder was macerated with 290 mL of 70% ethanol in a ratio of 1:10 (w/v) for 2-3 days at room temperature, with occasional stirring. The mixture is filtered, and the filtrate is evaporated at a temperature of about 60-70 C to obtain a concentrated extract.

Solid soap is prepared by mixing vegetable oils according to the planned formulation. Sodium hydroxide is dissolved in distilled water, cooled, and slowly added to the oil mixture while stirring until the trace stage is reached. H. rosa-sinensis leaf extract is then added according to the concentration treatment, followed by fragrance. The soap dough is poured into the mold, left for 24 hours to harden, removed from the mold, and preserved for approximately 21 days before testing.

Table 1 is presented to clarify the composition of the base oils used in each formulation. This table also shows that the amount of NaOH is adjusted across the oil base while the volume of water remains constant.

Table 1. Composition of Vegetable Oil Base for Solid Soap

Code	Coconut oil	Olive oil	Palm oil	NaOH	Water
A1	40%	30%	30%	14,87 gr	38 mL
A2	30%	35%	35%	14,44 grams	38 mL
A3	20%	40%	40%	14.02 gr	38 mL

Note: The extract treatment is V0 = 0% (0 g), V1 = 1% (1 g), V2 = 2% (2 g), and V3 = 3% (3 g).

The flow of the research is shown in Figure 1 so that the relationship between leaf preparation, extraction, saponification, preservation, and quality testing can be systematically followed.

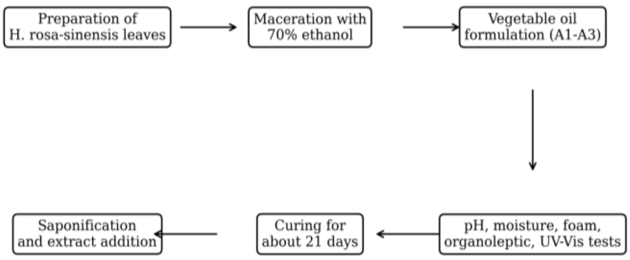

Figure 1. Research Flow of Solid Soap Formulation and Analysis

Quality Testing and Data Analysis

The pH of soap is measured by dissolving 1 g of soap in 10 mL of distilled water and testing the solution using a calibrated pH meter or pH indicator paper. The moisture content is determined by drying the oven at a temperature of about 105 C to a constant weight. The foam height is measured after shaking 1 g of soap in 10 mL of distilled water for 30 seconds, and the stability of the foam is calculated from the percentage of foam retained after 5 minutes. Organoleptic evaluation was conducted by 10 untrained panelists using a hedonic scale of 1-5 for color, aroma, texture, and overall preference.

The selected soap was analyzed using UV-Vis spectrophotometry in the range of 300-600 nm to determine the maximum wavelength and absorbance. The best candidates are selected based on combined physicochemical and organoleptic considerations. The data were analyzed descriptively by comparing the formulation trends and quality criteria adopted in the research protocol, especially pH 9-11 and the moisture content not exceeding 15%.

RESULTS AND DISCUSSION

Physicochemical quality of solid soap

The main physicochemical results are summarized in Table 2. This table is at the heart of the discussion as it shows the pH, moisture content, foam stability, and foam height of all combinations of vegetable oil formulations and extract concentrations.

Table 2. Physicochemical Quality of Solid Soap Samples

Sample	Oil base	Extracts	pH	Humidity (%)	Foam Stability (%)	Foam Height (cm)
F1	A1	V0	9.18	19.00	82.30	1.33
F2	A1	V1	9.28	15.33	82.36	1.33
F3	A1	V2	9.30	14.67	74.96	0.33
F4	A1	V3	9.18	17.33	76.43	1.33
F5	A2	V0	9.00	11.33	82.30	1.33

Sample	Oil base	Extracts	pH	Humidity (%)	Foam Stability (%)	Foam Height (cm)
F6	A2	V1	9.33	14.33	82.36	1.33
F7	A2	V2	9.34	13.00	84.96	0.33
F8	A2	V3	9.32	14.67	80.44	0.67
F9	A3	V0	9.34	12.00	79.96	0.33
F10	A3	V1	9.42	14.00	79.96	0.33
F11	A3	V2	9.41	11.00	88.89	1.00
F12	A3	V3	9.43	12.33	85.48	0.67

Note: F1-F12 represents a combination of A1-A3 and V0-V3. The value is reported as the average measurement for the same prepared sample.

The pH value ranges from 9.00 to 9.43. This range of bases is typical for soaps produced using sodium hydroxide and indicates that the saponification system produces fatty acid sodium salts. The highest pH is found at F12, while the lowest pH is found at F5. All samples were within the pH range adopted in the study protocol, indicating that none of the formulations produced an overly alkaline pH under the conditions tested.

The moisture content ranges from 11.00 to 19.00%. This parameter distinguishes the physical quality of soap more strongly than pH. F11 has the lowest moisture content, while F1 has the highest moisture content. When the maximum humidity criterion of 15% is applied, some samples meet the criteria, while F1 and F4 clearly exceed it and F2 slightly above it. Higher moisture content can reduce the hardness of the rod and shorten the storage stability; Therefore, the duration of water preservation and management must be carefully controlled.

Table 3. Average physicochemical values with vegetable oil formulations

Oil base	pH	Humidity (%)	Foam Stability (%)	Foam Height (cm)
A1	9.23	16.58	79.01	1.08
A2	9.25	13.33	82.51	0.83
A3	9.40	12.33	84.77	0.58

Note: A1 contains the highest proportion of coconut oil, while A3 contains a higher proportion of olive oil and palm oil.

The stability of the foam ranges from 74.96 to 88.89%, while the height of the foam ranges from 0.33 to 1.33 cm. F11 exhibits the highest foam stability, indicating that an A3 base with a 2% extract results in a more persistent foam structure than other treatments. These findings are consistent with plant soap studies that report that plant extracts can modify foam height and foam stability because the extract's constituents interact with the surfactant system and the soap matrix derived from the oil (Maripa & Ahmadi, 2023).

To clarify the influence of oil composition, Table 3 presents the average physicochemical values based on the vegetable oil base. Figure 2 then visualizes the two most distinguishing technical indicators, moisture content and foam stability.

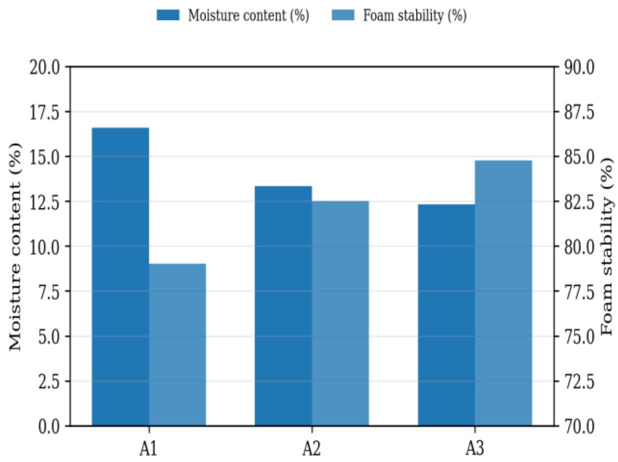

Figure 2. Average Moisture Content and Foam Stability with Oil Formulation

A3 base produces the lowest average moisture content (12.33%) and the highest average foam stability (84.77%). In contrast, A1 produces the highest average foam height (1.08 cm) but also the highest average moisture content (16.58%). These findings show the trade-off between the initial foam generation and overall technical stability. A higher proportion of coconut oil may contribute to foam formation, while a higher proportion of olive oil in A3 may favor a more stable stem matrix after pickling.

The effects of extract concentrations are summarized in Table 4. The lowest average moisture values were observed in V2 and V3 (12.89%), and the highest foam stability was observed in V2 (82.94%). However, the highest average foam height was observed at V0 (0.99 cm), suggesting that the addition of the extract did not necessarily increase the initial foam volume. A decrease in foam height in V1 and V2 can be caused by an interaction between the plant extract solids and the soap matrix, which can alter the viscosity, surface activity, or foam drainage.

Table 4. Average Physicochemical Values based on Extract Concentration

Extracts	pH	Humidity (%)	Foam Stability (%)	Foam Height (cm)
V0	9.17	14.11	81.32	0.99
V1	9.34	14.55	81.56	0.57
V2	9.35	12.89	82.94	0.55
V3	9.31	12.89	80.78	0.89

Note: V0 = 0%, V1 = 1%, V2 = 2%, and V3 = 3% H. rosa-sinensis leaf extract.

Organoleptic Responses and Formulas

Table 5 is included because consumer acceptance may differ from physicochemical performance. This helps to distinguish the most preferred sensory formulas from the formulas with the strongest technical profile.

Table 5. Average Organoleptic Score of Solid Soap Samples

Sample	Color	Aroma	Texture	Overall Preferences
F1	3.8	3.6	3.8	3.8
F2	3.3	3.2	3.5	3.5
F3	3.2	3.0	3.1	3.1
F4	2.7	3.3	3.0	3.0
F5	4.4	4.2	4.2	4.2
F6	3.7	3.6	3.9	3.9
F7	2.8	2.8	2.8	2.8
F8	2.6	3.0	3.1	3.1
F9	4.5	3.8	4.2	4.2
F10	3.9	3.5	3.4	3.4
F11	3.1	3.8	3.4	3.4
F12	3.4	3.6	3.8	3.8

Note: The score uses a scale of 1-5, where 1 = very dislike and 5 = very like; The evaluation involved 10 untrained panelists.

Organoleptic results showed that F5 obtained the highest score for aroma, texture, and overall preference (4.2 each), while F9 obtained the highest color score (4.5). Overall, F5 is the most preferred sensory sample. This result is important because the sample preferred by the panelists is not necessarily the one with the strongest moisture and foam stability profile.

The difference between sensory preferences and technical qualities should be considered in product development. Plant extracts can affect the color, aroma, and feel of the surface, but the most preferred sensory samples are not always the strongest technical candidates. This pattern has also been reported in plant extract soap formulations, where the concentration of the extract affects the pH, moisture content, foam properties, color, aroma, texture, and reception of panelists simultaneously (Maripa & Ahmadi, 2023).

UV-Vis characteristics of The Selected Sample

UV-Vis analysis was performed on samples containing A3 extract because this oil base has the lowest average moisture content and the highest average foam stability. Table 6 and Figure 3 are provided to show the absorption features of soap containing 1-3% H. rosa-sinensis leaf extract.

Table 6. Maximum wavelength of UV-Vis and absorbance of selected soap

Sample	Code	Extract Conc. (%)	Lambda Max (nm)	Absor-bance (AU)
F10	A3V1	1	376	0.751
F11	A3V2	2	374	0.750
F12	A3V3	3	377	0.747

Note: The UV-Vis scanning range is 300-600 nm.

The maximum wavelength of the selected soap is 374-377 nm, with an absorbance value of 0.747-0.751. This range is consistent with the Band I region commonly associated with flavonoid chromophores The presence of absorption in this region supports the persistence of extract-related compounds in the soap matrix, although UV-Vis data alone cannot identify individual molecules.

A small difference in absorbance also suggests that an increase in extract concentration from 1% to 3% does not increase absorbance linearly under the measurement conditions. This can occur because the extracts are scattered in a complex soap matrix, because the active components are partially bound or closed, or because the scanned solution reaches a limited response range. Further quantitative chromatographic or flavonoid analysis will be required to confirm the exact profile and concentration of the compound.

Comparison with The Quality Criteria and Limitations of The Study

Among the available criteria, pH and moisture content are the most direct parameters for comparison. All samples meet the adopted pH criteria, while the moisture content shows partial compliance. This shows that the conditions of the alkaline reaction are acceptable, but the preservation and reduction of water still require optimization. The current Indonesian standard for solid bath soap is SNI 3532:2021, which revises SNI 3532:2016 and specifies the quality requirements and testing methods of solid bath soap. Therefore, future studies should explicitly apply current standards and include all the necessary parameters.

The main limitation of this study is the absence of independent formulation replication. Although measurements are repeated on the same sample, independent batch replication is required to test the significance of the observed trend. Therefore, future soap formulation research should combine product quality testing with stronger experimental replication and reflective data interpretation, as applied chemical activities using soap products can support evidence-based problem-solving when formulation, testing, and evaluation are systematically designed (Ahmadi & Maripa, 2022).

CONCLUSION

The formulation of vegetable oil and the concentration of H. rosa-sinensis leaf extract resulted in measurable differences in the physicochemical qualities of solid soaps. All soaps are alkaline, with a pH value of 9.00-9.43. The moisture content ranges from 11.00 to 19.00%, the stability of the foam ranges from 74.96 to 88.89%, and the height of the foam ranges from 0.33 to 1.33 cm. The A3 oil base provides the most advantageous technical profile as it produces the lowest average moisture content and the highest average foam stability.

F5 is the most preferred sample in organoleptic assays, but F11 (A3 with 2% extract) is the strongest technical candidate because it contains extract, has the lowest moisture content, and exhibits the highest foam stability. UV-Vis analysis of soaps containing A3 extract showed a lambda max value of 374-377 nm and an absorbance value of 0.747-0.751, indicating flavonoid-related absorption in the soap matrix. Overall, this study supports the optimization of the combined composition of vegetable oil and the concentration of H. rosa-sinensis leaf extract in the formulation of natural solid soaps.

RECOMMENDATION

Future work should prepare an independent replica of the formulation so that inferential statistical analysis can be performed. Quality testing should also be expanded to include free alkalis, total fat materials, ethanol-insoluble materials, hardness, storage stability, irritant testing, microbial limits, and antibacterial activity.

Further chemical characterization of H. rosa-sinensis leaf extract in soap matrix is recommended using total phenolic content, total flavonoid content, FTIR, HPLC, or LC-MS. Sensory optimization must also be done by adjusting the color, fragrance, and concentration of the extract to align technical performance with consumer acceptance.

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