

Formulation and Evaluation of Liquid Soap Incorporated with *Salvia Rosmarinus* (Rosemary) Extract and *Lavandula* (Lavender) Essential Oil for Antibacterial and Antioxidant Effects

Nur Maisarah Abdul Aziz¹, Elizah Mohamed^{1*}

¹ Department of Chemical Engineering Technology, Faculty of Engineering Technology,
Universiti Tun Hussein Onn Malaysia (UTHM), Pagoh Education Hub, KM1, Jalan Panchor,
86400, Muar Johor, MALAYSIA

*Corresponding Author: elizah@uthm.edu.my

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Abstract

Skin sensitivity is a common concern, often worsened by harsh chemical products that disrupt the skin's natural balance. This study explores the development of a polyherbal liquid soap formulated with rosemary (*Salvia rosmarinus*) extracts and lavender (*Lavandula*) essential oil, designed to offer a gentle yet effective cleansing solution for sensitive skin. The soap harnesses the natural properties of these botanicals to reduce inflammation, support the skin barrier, and promote overall skin health. Fresh rosemary was extracted using advanced Soxhlet and Ultrasound-Assisted Extraction (UAE) methods, while lavender essential oil was incorporated for its therapeutic benefits. The final liquid soap formulation had a pH of 9.47, a value typical for conventional soaps yet safe for sensitive skin. Stability tests conducted at 4 °C and 25 °C showed no signs of degradation, confirming its suitability for long-term use. The soap's antioxidant activity was evaluated through the DPPH assay, demonstrating its potential to counteract oxidative damage. Additionally, antibacterial properties assessed via the Disc Diffusion method showed no inhibitory effects against *Staphylococcus epidermidis* and *Escherichia coli*, indicating limited antimicrobial efficacy. These findings suggest that this polyherbal liquid soap provides an effective, safe, and sustainable option for individuals with sensitive skin, blending natural ingredients with advanced extraction techniques to set a new standard for natural skincare products.

1.0 Introduction

Skin sensitivity is a common concern, often worsened by harsh chemical products that disrupt the skin's natural balance. This study explores the development of a polyherbal liquid soap formulated with rosemary (*Salvia rosmarinus*) extracts and lavender (*Lavandula*) essential oil. The main reason liquid soap is made is for its mild cleaning capabilities, which make it the perfect option for those with delicate skin. Liquid soap is meant to be a gentle but efficient approach to wash the skin without making it dry or irritating. The increased awareness of the need to use safe and environmentally friendly personal care products is one of the key drivers behind the

production of liquid soap for sensitive skin [1]. A lot of commercial soaps contain harsh chemicals that can cause skin irritation, dryness, and even disorders like psoriasis and eczema by depriving the skin of its natural oils.

Natural liquid soaps, on the other hand, are formulated without harsh chemicals using mild, plant-based ingredients. Because of their gentle and non-irritating formulation, these soaps are appropriate for those with sensitive skin. Natural liquid soap ingredients, like plant-based and essential oils, can help nourish and moisturize the skin in addition to their other advantages [2]. The growing market for sustainable and environmentally friendly personal hygiene products is another factor driving the production of liquid soap for sensitive skin. Natural liquid soaps are biodegradable and do not include any harsh ingredients that can contaminate the environment. This makes them a better option for the environment than store-bought soaps.

It might be difficult to formulate liquid soap for sensitive skin since a careful ingredient balance is needed to achieve a cleansing experience that is both mild and effective. To ensure that the soap effectively cleans the skin, mild and non-irritating components are chosen throughout the formulation process [3]. Utilizing natural materials can also be difficult because, depending on the circumstance, they might not work as well as synthetic ingredients. Nevertheless, the advantages of employing natural components outweigh the drawbacks because they provide those with sensitive skin a safer and more environmentally responsible option [4].

Furthermore, the performance and safety of liquid soap greatly depends on the addition of antibacterial and antioxidant properties. To stop germs from growing and avoid diseases, antibacterial ingredients like triclosan and chlorhexidine are frequently added to liquid soaps. To hinder bacteria's ability to survive and proliferate, these substances damage their cell membrane [5]. To shield the skin from oxidative stress and damage from free radicals, antioxidants such as vitamin E and beta-carotene are added to liquid soaps. Free radicals are known to damage skin and hasten ageing; antioxidants work to counteract these harmful agents.

Liquid soaps that contain both antioxidants and antibacterial ingredients can offer improved defense against skin damage and bacterial infections. For instance, a study discovered that liquid soap with both triclosan and vitamin E had better antioxidant and antibacterial qualities than soap with just one of these ingredients. In liquid soaps, natural components with antibacterial and antioxidant properties include essential oils and plant extracts [5]. The potential of rosemary essential oil as a natural antibacterial agent against both Gram-positive and Gram-negative bacteria is demonstrated by this study. The essential oil's antibacterial and antioxidant activities were also discovered to be connected, indicating that there may be more health benefits for people [6].

For this study, Rosemary extract and Lavender essential oil is chosen as one of the ingredients in this liquid soap. Some studies have shown that rosemary extract, derived from the leaves of *Rosmarinus officinalis* which belongs to the *Lamiaceae* family, show antioxidant, anti-inflammatory, antidepressant, antinociceptive, and antibacterial properties. [7]. Besides, Lavender essential oil, extracted from the flowers of *Lavandula angustifolia*, has been used for its calming and soothing effects and antimicrobial and antioxidant properties [8]. These natural ingredients offer a sustainable and eco-friendly alternative to synthetic fragrances and antimicrobial agents commonly used in personal care products.

The antibacterial efficacy of the formulated liquid soap was assessed using standard microbiological methods, such as the disc diffusion method or broth microdilution assay [9]. The antibacterial activity of the liquid soap was evaluated against common pathogens, such as *Staphylococcus epidermidis* and *Escherichia coli*, to determine its potential as a hygiene product while the antioxidant activity of the liquid soap formulation was evaluated using in vitro assays, such as the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical scavenging assay [9]. These assays will quantify the product's radical scavenging activity, indicating its potential as an antioxidant agent [10].

2.0 Materials and Methods

The research work was carried out at laboratory in Universiti Tun Hussein Onn Malaysia (UTHM) Campus Pagoh. All solvents, chemicals and reagents were prepared and provided by Material Technology Laboratory and Upstream Bioprocess Laboratory.

2.1 Material and Sample Preparation

The premium fresh *Salvia Rosmarinus* (rosemary) and *Lavandula* (lavender) essential oil were purchased from a Wong Agro Farm and Popoemart respectively. The fresh *Salvia Rosmarinus* leaves were being plucked one by one and placed inside a beaker and then washed with running tap water and rinsed with distilled water to eliminate any dirt and contaminants on the *Salvia Rosmarinus* leaves. Sharp scissors were used to cut the leaves into small pieces to increase their surface area. The *Salvia Rosmarinus* was then weighed accordingly and then placed in the beakers for future extraction.

2.2 Samples Extraction (*Salvia Rosmarinus*)

2.2.1 Soxhlet Extraction method

Rosemary leaves were extracted using a Soxhlet apparatus [11]. 30g of cleaned rosemary leaves were placed in four teabags and loaded into the Soxhlet extractor. Pure ethanol (250 mL) was used as the extraction solvent. The system was heated to ethanol's boiling point which is at 65°C, enabling vapor to pass through the condenser and drip into the extractor. The process was run continuously for 6 hours. After extraction, the ethanol solution containing the extract was cooled and collected. The solvent was then removed using a rotary evaporator and the extract was then filtered to remove plant debris, yielding the final rosemary extract [12].

2.2.2 Ultrasound Assisted Extraction (UAE) method

For UAE, 250 mL of 70% ethanol was prepared by diluting 175 mL of pure ethanol with 75 mL of distilled water [13]. 25g of cleaned rosemary leaves were added to the ethanol solution in a beaker. An ultrasound was used with settings of 40% amplitude for 30 minutes, followed by 50% amplitude for 15 minutes. Cavitation generated by the ultrasound probe facilitated the release of bioactive compounds from the rosemary leaves [14]. Following extraction, the solvent was removed using a rotary evaporator, and the extract was then filtered to remove plant debris and centrifuged at 4000 rpm for 15 minutes at 4°C to further purify the extract.

2.3 Formulation of liquid soap

Liquid soap formulation was set up as shown in Fig. 1



Fig. 1: Set up for the formulation of liquid soap

The liquid soap was prepared by combining the ingredients as in Table 1 in the following manner: Olive oil (250 g), potassium hydroxide (52 g), and vegetable glycerin (52 g) were measured and heated in a stainless-steel pot using an induction cooker. The temperature was carefully monitored and maintained between 75°C to 80°C until the mixture became translucent and glossy, indicating complete saponification. Distilled water (78 g) was mixed with dissolved potassium hydroxide to form a lye solution, which was then combined with the heated oil mixture. Once blended, the mixture was stick-blended until it reached a thick, pudding-like consistency. After achieving the desired consistency, the rosemary extract (6 ml), lavender essential oil (14 ml), and colorant (2.22 g) were added, and the mixture was stirred thoroughly. The final soap was then diluted with additional water as necessary, cooled, and poured into bottles for storage or use.

Table 1: Ingredients used in liquid soap

Ingredient	Percentage (%)	Weight(g)
Olive Oil	56.41	250.00
Potassium Hydroxide	11.71	52.00
Vegetable Glycerin	11.71	52.00
Distilled Water	17.57	78.00
Rosemary Extract (6 ml)	1.29	5.70
Lavender Essential Oil (14 ml)	3.30	12.74
Colorant	0.49	2.22
Total	100	450.38

2.4 pH test

The pH of the rosemary extract and the formulated liquid soap was measured to ensure compliance with acceptable ranges. Initially, pH paper was used for a preliminary assessment by dipping a strip into the solution and comparing the resulting color change with the reference chart [15]. For greater accuracy, a digital pH meter and pH probe were employed. The pH probe was rinsed with distilled water and immersed in rosemary extract to

confirm an acidic pH (orange to yellow range on the pH scale). Similarly, the pH of the liquid soap, containing rosemary extract and lavender essential oil, was measured to confirm it was within the alkaline range (9–10) and was adjusted by using citric acid. As essential oils are hydrophobic and do not dissolve in water, the pH of lavender essential oil could not be directly measured. Since pH is a measure of hydrogen ion concentration in aqueous systems, pure essential oils lack a detectable pH. While the pH of an emulsion or aqueous-based system containing essential oils could be measured, this was not applicable in this investigation as lavender essential oil was used in its pure form.

2.5 Stability test

Barel identified three types of stability testing: microbiological tests (assessing color, odor, pH, viscosity, texture, flow, and emulsion stability), physical and chemical integrity tests (measuring mold, yeast, and bacterial contamination), and packaging tests (evaluating packaging impact on the formulation) [16]. In this study, stability testing was adapted due to resource constraints. A one-month short-term stability study was conducted under two storage conditions: room temperature (~25°C) and cold temperature (4°C). Samples were stored in appropriate containers and examined weekly for changes in color, odor, phase separation, and pH. Physical properties such as color, odor, and clarity were tracked. Samples were tested at weekly intervals and analyzed [17].

2.6 Antibacterial test

The antibacterial activity of both rosemary extract and the formulated liquid soap was assessed using the disc diffusion susceptibility method. This method, as outlined by Jan Hudzicki, involves six main steps: collecting culture plates, preparing the media, and preparing the bacterial subculture. Agar plates were inoculated with *Staphylococcus epidermidis* and *Escherichia coli* to test antibacterial efficacy [18]. Whatman No. 3 filter paper was used to prepare discs approximately 6 mm in diameter, which were soaked in test compounds at dilutions of 1:20 (10%) and 1:10 (5%). These impregnated discs were then placed on the agar surface, and the plates were incubated at 37°C for 24 hours. During the incubation period, the antimicrobial agents diffused into the agar, inhibiting the growth of *S. epidermidis* and *E. coli*. The diameters of the resulting inhibition zones were measured and compared to evaluate the antibacterial properties of the test samples.

2.7 Antioxidant test

The antioxidant activity of the samples was evaluated using the DPPH radical scavenging assay. To prepare a 1 mM DPPH solution, 4 mg of DPPH was dissolved in 100 mL of 99% methanol [19], ensuring a homogeneous mixture through thorough shaking. Plant extract volumes of 0.30, 0.15, and 0.03 µL were pipetted and diluted with methanol to obtain a final volume of 3 mL. L-ascorbic acid served as the standard solution; 0.1 g of L-ascorbic acid was dissolved in 10 mL of methanol, and serial dilutions were prepared to match the concentrations of the plant extracts. Subsequently, 1 mL of the prepared DPPH solution was added to each test tube, mixed thoroughly, and left to react in a dark, cool environment for 30 minutes. The absorbance of each sample was then measured at a wavelength of 517 nm using a UV-vis spectrophotometer. The percentage of DPPH radical scavenging activity was calculated using the following equation:

$$\text{Radical Scavenging Assay (\%)} = \frac{A_{\text{control}} - A_{\text{sample}}}{A_{\text{control}}} \times 100 \quad \text{Eq 1}$$

Where A_{sample} is absorbance of the extract and A_{control} is absorbance of control. Next, the graph inhibition % against concentration was plotted for evaluation and determination of IC_{50} value. All the steps were repeated for formulated liquid soap.

3.0 Result and Discussion

In this study, rosemary was extracted as the sole herbal plant, while lavender essential oil was sourced from Popoemart to incorporate into a formulated liquid soap. The liquid soap was evaluated for its physicochemical properties, specifically pH and stability. Additionally, its effectiveness was assessed through antioxidant and antibacterial tests, using the DPPH radical scavenging assay and the disc diffusion method, respectively. This study aimed to formulate and evaluate the effectiveness of liquid soap incorporating these natural ingredients, highlighting its potential for promoting skin health and reducing side effects.

3.1 Analysis of the herbal extract

3.1.1 Analysis of pH test

According to Fig. 2, rosemary extract obtained from Soxhlet extraction has a higher pH of 7.15 compared to the one obtained from UAE, which is 6.87. Theoretically, the pH for *Salvia Rosmarinus* (rosemary) obtained from Soxhlet and UAE ranges from 4.0 to 6.0 [20] and 4.5 to 5.5 [21] respectively. However, the pH value obtained from the extracted rosemary is slightly alkaline.

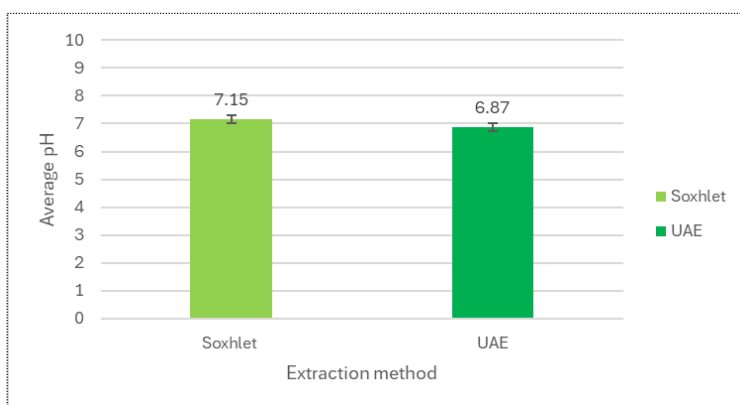


Fig. 2: The pH value of the herbal extract, rosemary by using Soxhlet and UAE method. n=3

The comparison between the two rosemary extraction methods, Soxhlet and UAE, reveals notable differences in pH values, highlighting the impact of the extraction process on the final extract. The Soxhlet method produced an extract with a pH of 7.15, while the UAE method yielded a slightly more acidic extract with a pH of 6.87. These findings are slightly alkaline for both methods, deviating from the expected pH ranges reported in previous studies. Abandansarie et al. (2019) suggested that the pH of Soxhlet extracts typically falls between 4.0 and 6.0, while Dhouibi et al. (2023) reported a range of 4.5 to 5.5 for UAE extraction.

The deviation observed in this study could stem from differences in experimental conditions, such as solvent concentration, extraction parameters, or post-extraction processes, which may influence the pH of the extracts. The bar graph further visualizes these results, with the Soxhlet extraction bar showing a pH above 7.0, indicating a neutral to slightly basic extract. On the other hand, the UAE method's bar is lower, reflecting a more acidic extract. This discrepancy between the two methods suggests that variations in extraction conditions, such as solvent exposure time, temperature, and extraction mechanisms, may be responsible for the difference in pH. Despite the deviation from expected pH values, the uniformity of the results across trials demonstrates the reliability and consistency of the measurement process.

3.1.2 Analysis of Antimicrobial Test

According to Fig. 3, rosemary extract and lavender essential oil showed a higher sensitivity to gram-positive bacteria (*S. epidermidis*) than to gram-negative bacteria (*E. coli*), as indicated by a larger inhibition zone for *S. epidermidis*. This difference in sensitivity is largely due to the distinct cell wall structures of these bacteria. Gram-positive bacteria have a thick peptidoglycan layer (20-80 nm) that retains antimicrobial agents effectively, while gram-negative bacteria possess a thin peptidoglycan layer (5-10 nm) and an additional outer membrane, which can restrict the penetration of these compounds. Nevertheless, both herbal extracts demonstrate moderate antimicrobial activity, with a zone of inhibition (ZOI) ranging from 5 cm to 9.5 cm, making them suitable for incorporation into formulated liquid soap according to Zhao [22].

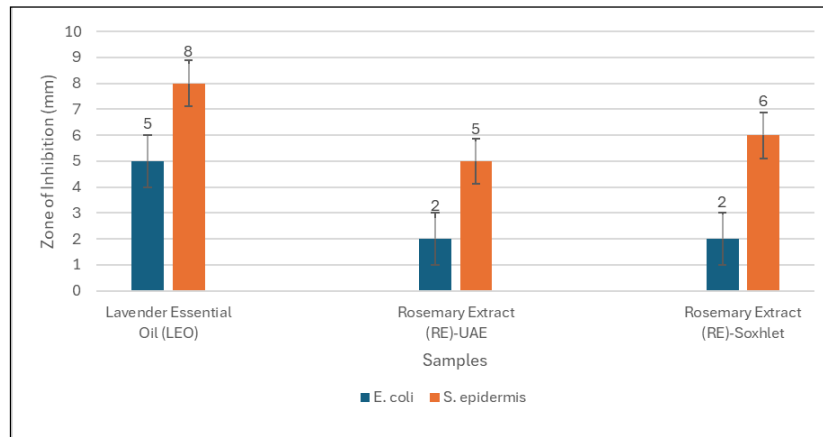


Fig. 3: Diameter of the zone of inhibition (ZOI) for the rosemary extract and lavender essential oil against *E. coli* and *S. epidermis*. n=3

3.1.3 Analysis of Antioxidant Test

Fig. 4 illustrates the correlation between the percentage of the radical scavenging assay and the sample concentration. The IC_{50} value for each sample was determined by using the graph. The IC_{50} value represents the minimum concentration of the sample extract needed to eliminate 50% of the DPPH. As scavenging activity increases, the IC_{50} value decreases. It demonstrates that the DPPH test verified the varying free radical-scavenging activities of *C. asiatica* extract, *A. vera* gel extract, and tea tree oil, with IC_{50} values ranging from 0.05 to 0.89 $\mu\text{g/ml}$.

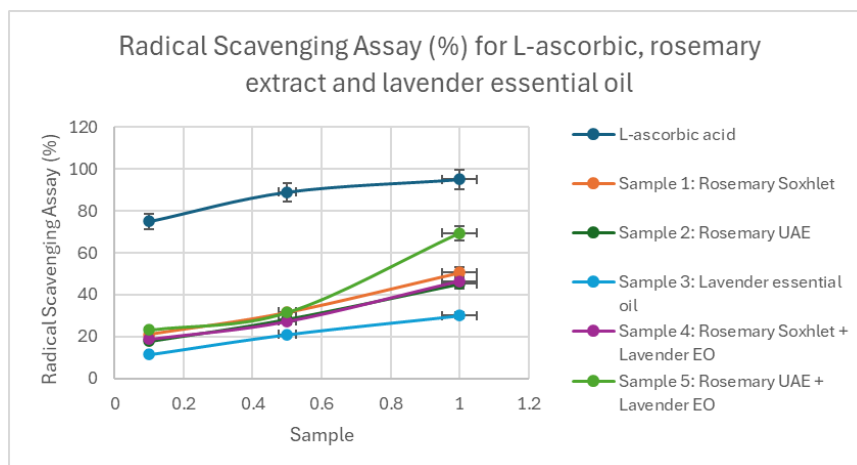


Fig. 4: Radical Scavenging Assay for L-ascorbic, rosemary extract and lavender essential oil. n=3

Previous studies have indicated that extracts with IC_{50} values ranging from 50 to 100 mg/mL demonstrate moderate antioxidant activity, while those with IC_{50} values below 50 mg/mL exhibit strong antioxidant activity [23]. Accordingly, all herbal extracts analyzed in this study show notable antioxidant properties. The potential of rosemary extract and lavender essential oil for scavenging free radicals is particularly promising for application in dermatological cosmetic formulations.

3.2 Analysis of the formulated liquid soap

3.2.1 Analysis of pH test

Based on Fig. 5, the pH of the formulated liquid soap before and after addition of rosemary extract and lavender essential oil falls to 9.71 and 9.47 respectively.

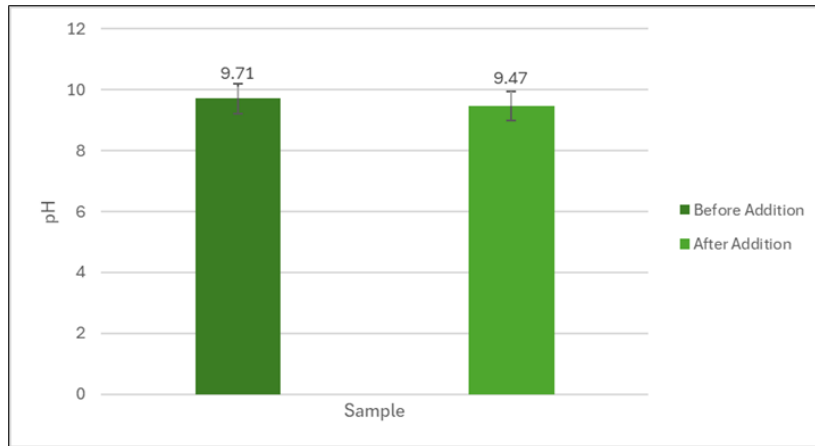


Fig. 5: The pH value of the formulated liquid soap before and after addition of rosemary extract and lavender essential oil. n=3

The liquid soap formulation is intended for external use, requiring its pH to align with the optimal range for effective cleansing without causing skin irritation. Research suggests that the ideal pH range for formulated liquid soap is between 9 and 10.5 [24]. Maintaining this pH range ensures the soap’s chemical stability and effectiveness while avoiding excessive acidity or alkalinity, which could compromise its performance or shelf life. Thus, to maintain the pH, 12 mL of citric acid was added to the formulated liquid soap. Therefore, the formulated liquid soap in this study falls within the recommended pH range, making it suitable for use and more effective compared to formulations outside this range.

3.2.2 Analysis of antibacterial test

Based on research on where antibiotics such as dalbavancin were used as positive control against *S. epidermidis*, it shows ZOI of 10mm [25] while positive control against *E. coli* by using ciprofloxacin, it shows ZOI of 15mm [26]. As for negative control, sterile water was used but showed no production of inhibition zone, indicating no antibacterial activity. Based on Table 2, the antibacterial activity of four liquid soap samples comprising a combination of lavender essential oil (LEO) and rosemary extract from UAE extraction was evaluated against *E. coli* and *S. epidermidis* at different dilutions which are 1:10 and 1:20.

Table 2: Antimicrobial susceptibility testing using the Kirby-Bauer disc diffusion method and microbial inhibition

Concentration	Sample Code	Bacteria Tested	Observation	ZOI (mm)	Remarks
1:10 dilution	Sample 1	<i>E. coli</i>	No visible bacterial growth in the inoculated area.	No measurable ZOI	Indicates strong antibacterial activity.
	Sample 2	<i>S. epidermidis</i>	No visible bacterial growth in the inoculated area.	No measurable ZOI	Indicates strong antibacterial activity.

1:20 dilution	Sample 3	<i>E. coli</i>	No visible bacterial growth in the inoculated area.	No measurable ZOI	Indicates strong antibacterial activity.
	Sample 4	<i>S. epidermidis</i>	No visible bacterial growth in the inoculated area.	No measurable ZOI	Indicates strong antibacterial activity.

At both the 1:10 and 1:20 dilutions, none of the samples showed a quantifiable zone of inhibition (ZOI), indicating that while bacterial growth was not observable in the inoculated areas, the antibacterial activity may have been bacteriostatic rather than bactericidal, which could explain the lack of visible ZOI [27]. These findings indicate that the examined liquid soap samples may have antibacterial capabilities, but more modification and testing (such as raising the concentration of active components or testing various microbial strains) may be required to validate their efficiency. The absence of apparent bacterial growth in the inoculated portions of all samples, including those with *E. coli* and *S. epidermidis*, indicates potential antibacterial effects, although the lack of a distinct ZOI supports bacteriostatic rather than bactericidal action. Certain essential oils, such as lavender, can restrict bacterial growth without killing the bacterium, which could explain the lack of ZOI despite the observed growth suppression [22].

3.2.3 Analysis of antioxidant test

Fig. 6 depicts the relationship between the percentage of the Radical Scavenging Assay (RSA) and the sample concentration. The IC_{50} value for each sample was calculated by utilising the graph. The IC_{50} value denotes the lowest concentration of the sample required to scavenge 50% of the DPPH. As the scavenging action increases, the IC_{50} value decreases. Based on Fig. 6, the IC_{50} value for polyherbal liquid soap is at 5.98 mg/ml

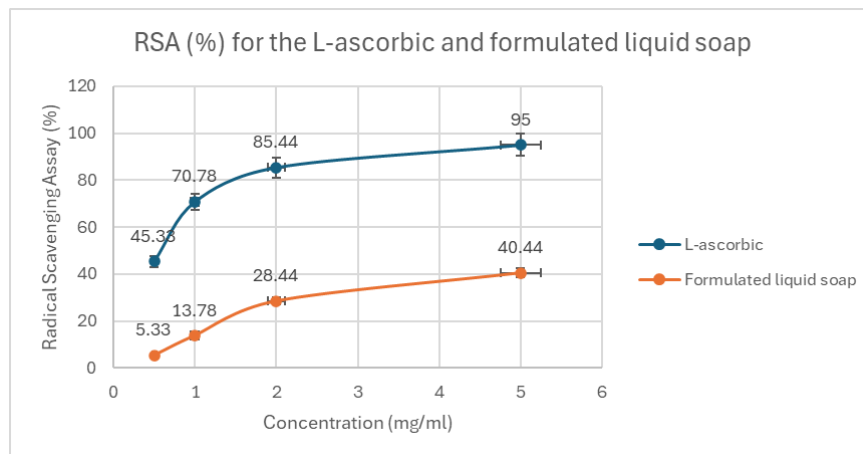


Fig. 6: Radical Scavenging Assay for L-ascorbic and polyherbal formulated liquid soap. n=3

As seen by the rising Radical Scavenging Activity (RSA) percentages from Fig.6, the graph shows a significant increase in Radical Scavenging Activity (RSA%) from $5.33 \pm 0.21\%$ at 0.5 mg/ml to $40.44 \pm 0.15\%$ at 5.0 mg/ml, indicating a strong correlation between concentration and antioxidant capacity. The steepest increase occurred between 0.5 mg/ml and 2.0 mg/ml, followed by a plateau as the antioxidant capacity approaches saturation. The small error bars indicate reliable and consistent results, which align with Gulcin & Alwasel (2023) research. The observed IC_{50} value indicates that the formulated liquid soap exhibits strong antioxidant activity with an IC_{50} value lower than 10 $\mu\text{g/ml}$ [28]. As the lowest IC_{50} value corresponds to the highest antioxidant activity, polyherbal liquid soap contained significantly higher antioxidants than basic liquid soap.

3.2.4 Analysis of stability test

No phase separation occurred and the colour of the formulated liquid soap remained unchanged after 4 weeks of stability test as shown in Fig. 7 below.



Fig. 7: The condition of formulated liquid soap after stability test

In the stability test, critical aspects such as color, texture, odor, and phase separation were carefully monitored for the formulated liquid soap, both before and after the addition of rosemary extract and lavender essential oil. At both tested temperatures (4°C and 25°C) over the four-week duration, the color of the liquid soap remained consistent, either clear or pale green, with a smooth and uniform texture. The odor remained unchanged, and the viscosity was moderate under all conditions. Notably, no phase separation occurred in any of the formulations throughout the test period, indicating excellent stability. The addition of rosemary extract and lavender essential oil may have contributed to this stability by enhancing the liquid soap's resilience to temperature variations. These herbal components are known for their stabilizing properties and may have played a key role in maintaining the integrity of the formulation under the tested conditions.

4.0 Conclusion

Based on this research, it can be concluded that the formulated liquid soap incorporated with rosemary extract and lavender essential oil was successfully developed and demonstrated superior properties compared to the basic liquid soap formulation. The findings contribute to the development of a potentially more effective, safe, and sustainable cleansing product that leverages the benefits of herbal extracts, catering to consumer demand for natural and eco-friendly personal care solutions. These promising results provide a foundation for further research to evaluate the liquid soap's efficacy and safety, with future studies potentially focusing on extended stability tests and clinical trials for broader applications.

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References

- [1] Shahirah, S. (2024, June 12). Liquid vs bar soaps: Which is better? Sinar Daily. <https://www.sinardaily.my/article/218810/culture/liquid-vs-bar-soaps-which-isbetter>
- [2] Mijaljica, D., Spada, F., & Harrison, I. P. (2022). Skin Cleansing without or with Compromise: Soaps and Syndets. *Molecules*, 27(6), 2010. <https://doi.org/10.3390/molecules27062010>
- [3] Uzwanania, F., Ningrum, R. S., & O, S. R. (2020). FORMULATION OF LIQUID HAND SOAP MADE FROM NEEM SEED OIL AND LEMONGRASS ESSENTIAL OIL. *Indonesian Journal of Applied Research (IJAR)*, 1(3), 155-162. <https://doi.org/10.30997/ijar.v1i3.79>
- [4] Bom, S., Jorge, J., Ribeiro, H., & Marto, J. (2019). A step forward on sustainability in the cosmetics industry: A review. *Journal of Cleaner Production*, 225, 270–290. <https://doi.org/10.1016/j.jclepro.2019.03.255>

- [5] Yu, J. J., Manus, M. B., Mueller, O., Windsor, S. C., Horvath, J. E., & Nunn, C. L. (2018). Antibacterial soap use impacts skin microbial communities in rural Madagascar. *PloS One*, 13(8), e0199899
- [6] Nieto, G., Ros, G., & Castillo, J. (2018). Antioxidant and Antimicrobial Properties of Rosemary (*Rosmarinus officinalis*, L.): A Review. *Medicines*, 5(3), 98.
- [7] De Macedo, L. M., Santos, É. M. D., Ataide, J. A., De Souza E Silva, G. T., De Oliveira Guarnieri, J. P., Lancellotti M., Jozala, Â. F., Rosa, P., & Mazzola, P. G. (2022). Development and Evaluation of an Antimicrobial Formulation Containing *Rosmarinus officinalis*. *Molecules/Molecules Online/Molecules Annual*, 27(16), 5049.
- [8] Badr, M. M., Badawy, M. E. I., & Taktak, N. E. M. (2021). Characterization, antimicrobial activity, and antioxidant activity of the nanoemulsions of *Lavandula spica* essential oil and its main monoterpenes. *Journal of Drug Delivery Science and Technology*, 65, 69 102732.
- [9] Williams, L. (2024). The best antibacterial body washes that are tough on odors and soft on skin. *Verywell Fit*. <https://www.verywellfit.com/best-antibacterialbody-wash->
- [10] Thongphichai, W., Pongkittiphan, V., Laorpaksa, A., Wiwatcharakornkul, W., & Sukrong, S. (2023). Antimicrobial Activity against Foodborne Pathogens and Antioxidant Activity of Plant Leaves Traditionally Used as Food Packaging. *Foods*, 12(12), 2409. <https://doi.org/10.3390/foods12122409>
- [11] Redfern, J., Kinninmonth, M., Burdass, D., & Verran, J. (2014b). Using Soxhlet ethanol extraction to produce and test plant material (Essential oils) for their antimicrobial properties. *Journal of Microbiology and Biology Education*, 15(1), 45–46. <https://doi.org/10.1128/jmbe.v15i1.656>
- [12] Vieira, C., Rebocho, S., Craveiro, R., Paiva, A., & Duarte, A. R. C. (2022). Selective extraction and stabilization of bioactive compounds from rosemary leaves using a biphasic NADES. *Frontiers in Chemistry*, 10. <https://doi.org/10.3389/fchem.2022.954835>
- [13] Lee, J. J., & Yoon, K. Y. (2022). Ultrasound-Assisted Extractions for Improving the Recovery of Phenolics and Charantin from Bitter Melon and for Increasing the Antioxidant, Antidiabetic and Anti-Obesity Activities of Its Extracts. *Polish Journal of Food and Nutrition Sciences*, 141–150. <https://doi.org/10.31883/pjfn/149434>
- [14] Laina, K. T., Drosou, C., Stergiopoulos, C., Eleni, P. M., & Krokida, M. (2024). Optimization of Combined Ultrasound and Microwave-Assisted Extraction for Enhanced Bioactive Compounds Recovery from Four Medicinal Plants: Oregano, Rosemary, Hypericum, and Chamomile. *Molecules*, 29(23), 5773. <https://doi.org/10.3390/molecules29235773>
- [15] Fotta, A. (2020). Science At Play: Red Cabbage Juice Indicator. *Down To A Science*. 72 Retrieved from <https://ctsciencecenter.org/blog/science-at-play-red-cabbage-juiceindicator/>
- [16] Duginske, S. (2025c, January 10). Cosmetic Shelf Life: Stability Testing Insights - Parameter. *Parameter*. <https://humiditycontrol.com/blog/stability-testing-cosmetics-shelf-life/>
- [17] Hile, C. (2024, November 12). Stability Testing for Pharmaceuticals & more - parameter. *Parameter*. <https://humiditycontrol.com/blog/what-is-stability-testing/>
- [18] Blinova, A., Blinov, A., Kravtsov, A., Nagdalian, A., Rekhman, Z., Gvozdenko, A., Kolodkin, M., Filippov, D., Askerova, A., Golik, A., Serov, A., Shariati, M. A., Alharbi, N. S., Kadaikunnan, S., & Thiruvengadam, M. (2023). Synthesis, Characterization and Potential Antimicrobial Activity of Selenium Nanoparticles Stabilized with Cetyltrimethylammonium Chloride. *Nanomaterials (Basel, Switzerland)*, 13(24), 3128. <https://doi.org/10.3390/nano13243128>
- [19] Bibi, N., Shah, M. H., Khan, N., Al-Hashimi, A., Elshikh, M. S., Iqbal, A., Ahmad, S., & Abbasi, A. M. (2022). Variations in Total Phenolic, Total Flavonoid Contents, and Free Radicals' Scavenging Potential of Onion Varieties Planted under Diverse Environmental Conditions. *Plants (Basel, Switzerland)*, 11(7), 950. <https://doi.org/10.3390/plants11070950>
- [20] Abandansarie, S. S. R., Ariaii, P., & Langerodi, M. C. (2019). Effects of encapsulated rosemary extract on oxidative and microbiological stability of beef meat during refrigerated storage. *Food Science & Nutrition*, 7(12), 3969–3978. <https://doi.org/10.1002/fsn3.1258>
- [21] Dhouibi, N., Manuguerra, S., Arena, R., Messina, C. M., Santulli, A., Kacem, S., Dhaouadi, H., & Mahdhi, A. (2023b). Impact of the Extraction Method on the Chemical Composition and Antioxidant Potency of *Rosmarinus officinalis* L. Extracts. *Metabolites*, 13(2), 290. <https://doi.org/10.3390/metabo13020290>

- [22] Zhao, A., Zhang, Y., Li, F., Chen, L., & Huang, X. (2023). Analysis of the antibacterial properties of compound essential oil and the main antibacterial components of unilateral essential oils. *Molecules*, 28(17), 6304. <https://doi.org/10.3390/molecules28176304>
- [23] Soltanian, S., Sheikhabahaei, M., Mirtadzadini, M., & Khandani, B. K. (2020). Evaluation of anticancer, antioxidant and antibacterial properties of methanol extract of three *Acantholimon* Boiss. species. *DOAJ (DOAJ: Directory of Open Access Journals)*, 10(6), 641–652. <https://doaj.org/article/115cdb9c0c484f94a03d394e04d36c3d>
- [24] Tarun, J., Susan, J., Suria, J., Susan, V., & Criton, S. (2014c). Evaluation of pH of bathing soaps and shampoos for skin and hair care. *Indian Journal of Dermatology*, 59(5), 442. <https://doi.org/10.4103/0019-5154.139861>
- [25] Chiera, S., Bosco, F., Mollea, C., Piscitello, A., Sethi, R., Nollo, G., Caola, I., & Tessarolo, F. (2023). *Staphylococcus epidermidis* is a safer surrogate of *Staphylococcus aureus* in testing bacterial filtration efficiency of face masks. *Scientific Reports*, 13(1). <https://doi.org/10.1038/s41598-023-49005-4>
- [26] Serafin, P., Kowalczyk, P., Mollica, A., Stefanucci, A., Laskowska, A. K., Zawadzka, M., Kramkowski, K., & Kleczkowska, P. (2023). Evaluation of Antimicrobial Activities against Various *E. coli* Strains of a Novel Hybrid Peptide—LENART01. *Molecules*, 28(13), 4955. <https://doi.org/10.3390/molecules28134955>
- [27] Team, C. (2024, May 16). Bacteriostatic and bactericidal: key differences in mechanisms. Swiss Anti-Bacterial & Anti-Viral Testing Laboratory, ISO Certified | MIS. <https://microbe-investigations.com/key-differences-in-mechanism-of-bacteriostatic-and-bactericidal-actions-in-drug-development/>
- [28] Aulifa, D. L. (2020). Formulation of Serum Gel Containing *Angelica keiskei* Leaf Extract as an Antioxidant and Tyrosinase Enzyme Inhibitor. *Int J Appl Pharm. bolites*, 13(2), 290. <https://doi.org/10.3390/metabo13020290>