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Formulation and evaluation of herbal soap: A comprehensive research study

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Abstract
The increasing consumer demand for natural and eco-friendly personal care products has led to a surge in interest in herbal formulations, particularly in developing herbal soaps. This research study aims to formulate and evaluate herbal soap using selected medicinal plant extracts known for their antimicrobial, antioxidant, and skin-nourishing properties. The primary objective was to create a safe, effective, and environmentally sustainable herbal soap while assessing its physicochemical properties, antimicrobial efficacy, and skin compatibility. Herbal soap samples were prepared using traditional soap-making techniques with standardised concentrations of plant extracts such as neem, turmeric, and 4 .aloe ver00000a. Comprehensive evaluations included pH measurement, hardness, lather quality, moisture content, and microbial contamination tests. Additionally, antimicrobial activity was assessed against common skin pathogens, and skin irritation potential was evaluated through patch tests on human volunteers. The results demonstrated that the formulated herbal soaps exhibited excellent cleansing ability, stable physicochemical characteristics, and significant antimicrobial activity, particularly against Staphylococcus aureus and Candida albicans. No adverse skin reactions were reported, indicating good skin compatibility. This study concludes that herbal soap formulations incorporating medicinal plant extracts offer a promising alternative to synthetic soaps by providing enhanced skin benefits and reducing environmental impact. These findings support the potential commercialisation of herbal soaps as a natural, therapeutic, and sustainable personal care product, contributing to the growing market for herbal cosmetics.

Keywords: Herbal Soap, Medicinal Plant Extracts, Antimicrobial Activity, Physicochemical Evaluation, Skin Compatibility, Natural Cosmetics, Sustainable Personal Care

Introduction

In recent decades, there has been a growing global shift toward natural and sustainable products, particularly in the personal care and cosmetic industry. Among these, herbal soaps have gained considerable attention due to their perceived safety, skin compatibility, and therapeutic properties. Traditional soaps, typically composed of synthetic detergents and chemical additives, have raised concerns regarding their environmental impact and potential adverse effects on human skin, such as dryness, irritation, and allergic reactions (Draelos, 2018). Consequently, the demand for herbal-based alternatives that incorporate medicinal plant extracts has surged, driven by increased consumer awareness of health and environmental sustainability (Chatterjee & Pakrashi, 2020) [1].

Background and Context

Soap-making is an ancient practice, with the earliest records dating back to Babylonian civilisation around 2800 BCE, where animal fats and wood ash were combined to create cleansing agents (Raghunandan, 2016). Traditional soap formulations often relied on natural ingredients, but with industrialisation, synthetic chemicals have dominated the market. While synthetic soaps are effective cleaners, they can disrupt the skin's natural barrier, leading to dryness, irritation, and even allergic dermatitis (Lodén & Maibach, 2012) [4]. Moreover, synthetic ingredients like sulfates and parabens have raised environmental and health concerns, spurring interest in natural, biodegradable alternatives.

Herbal soaps typically incorporate plant extracts known for their antimicrobial, antioxidant, and skin-conditioning properties. Popular botanicals such as neem (Azadirachta indica), turmeric (Curcuma longa), aloe vera (Aloe barbadensis), and tea tree oil (Melaleuca alternifolia) have long been used in traditional medicine for skin care due to their bioactive compounds, including flavonoids, tannins, and essential oils (Kumar et al., 2019) [2, 3]. These compounds exhibit a broad spectrum of biological activities, such as antibacterial, antifungal, anti-inflammatory, and wound-healing effects, making herbal soaps beneficial beyond mere cleansing (Singh & Sharma, 2021) [10].

Importance of the Research

The personal care market is expected to continue growing, with a significant segment focused on natural and organic products. According to a report by Grand View Research (2023), the global herbal cosmetics market was valued at approximately USD 10.5 billion in 2022 and is projected to expand at a compound annual growth rate (CAGR) of 9.2% through 2030. This trend reflects increasing consumer preference for products that are both health-conscious and environmentally friendly. Herbal soaps align with this demand by offering multifunctional benefits: cleansing, nourishing, and protecting the skin, often with minimal environmental footprint due to biodegradable ingredients.

Despite the popularity of herbal soaps, there remains a need for rigorous scientific formulation and evaluation to ensure efficacy, safety, and stability. Many commercial herbal soaps lack standardisation or are based on anecdotal evidence rather than empirical research, which can affect their therapeutic claims and user satisfaction (Mishra & Tripathi, 2020) [5]. Furthermore, the quality control of herbal ingredients varies widely depending on geographic source, extraction methods, and storage conditions, which directly impacts the final product's performance (Patel et al., 2022) [7].

Literature Review

Several studies have investigated the formulation of herbal soaps using various plant extracts and assessed their physicochemical properties and biological activities. For example, a study by Rani et al. (2021) [8] formulated neem and turmeric-based soaps and reported significant antimicrobial activity against *Staphylococcus aureus* and *Escherichia coli*, along with favourable pH and lather characteristics. Similarly, Kumar and Rao (2019) [2, 3] developed a herbal soap containing aloe vera and green tea extracts, highlighting its moisturising and antioxidant potential, which contributed to improved skin hydration and protection against oxidative stress.

Other research has focused on specific properties such as antimicrobial efficacy and skin safety. Singh et al. (2020) [10] evaluated a soap formulated with tea tree oil and found potent antifungal activity against *Candida albicans*, suggesting its suitability for treating fungal skin infections. Moreover, patch test studies conducted by Naik et al. (2018) [6] demonstrated that soaps with natural extracts generally exhibited low irritation potential, making them safe for sensitive skin.

While these studies contribute valuable insights, most have limitations in scope, such as small sample sizes, lack of comprehensive stability studies, or insufficient evaluation of the full range of physicochemical parameters. Furthermore, comparisons among different herbal extracts and optimisation of their concentrations for maximal efficacy and minimal adverse effects remain underexplored.

Research Gaps and Unanswered Questions

Despite the promising attributes of herbal soaps, several gaps exist in the literature. Firstly, there is a scarcity of standardised protocols for evaluating herbal soap formulations comprehensively, combining physicochemical, microbiological, and dermatological assessments in a single study. Secondly, most studies focus on single or limited extracts without exploring the synergistic effects of multiple botanicals, which could enhance the soap's overall performance. Thirdly, there is limited data on the long-term stability of herbal soaps, which is critical for their commercial viability. Finally, many formulations lack detailed toxicological evaluations to ensure safety, especially for users with sensitive or compromised skin.

This study addresses these gaps by formulating herbal soaps incorporating multiple medicinal plant extracts and systematically evaluating their physicochemical properties, antimicrobial activity, and skin compatibility. By doing so, it aims to develop a product that not only meets consumer demand for natural skincare but also adheres to scientific rigour and quality standards.

Objectives of the Study

The primary objective of this research is to formulate and evaluate herbal soap using selected medicinal plant extracts known for their therapeutic properties. Specific aims include:

1. To prepare herbal soap formulations incorporating neem, turmeric, and aloe vera extracts using traditional soap-making techniques.
2. To assess the physicochemical properties of the formulated soaps, including pH, hardness, moisture content, lathering ability, and stability.
3. To evaluate the antimicrobial activity of the herbal soaps against common skin pathogens such as Staphylococcus aureus, Escherichia coli, and Candida albicans.
4. To assess the skin compatibility and irritation potential of the herbal soap formulations through patch testing on human volunteers.
5. To analyse the potential of the formulated herbal soaps as sustainable and effective alternatives to synthetic soaps in personal care.

Methods

This research employed a quantitative experimental design to formulate herbal soap using selected medicinal plant extracts and systematically evaluate its physicochemical properties, antimicrobial activity, and skin compatibility. The study was conducted in a controlled laboratory environment over a period of six months to ensure consistency in preparation and analysis.

The sample preparation involved sourcing high-quality raw materials from certified suppliers. Fresh leaves of *Azadirachta indica* (neem), rhizomes of *Curcuma longa* (turmeric), and gel extracted from *Aloe barbadensis* (aloe vera) were procured from an organic herbal farm. Each plant material was authenticated by a botanist to ensure species accuracy. The plant extracts were prepared using standard solvent extraction methods; neem and turmeric powders were subjected to ethanol extraction, while aloe vera gel was used in its fresh form after filtration to remove impurities.

Soap formulations were prepared using the cold process soap-making technique. The basic soap base comprised a mixture of coconut oil, palm oil, and castor oil, saponified using sodium hydroxide (NaOH) at carefully controlled temperatures. Three different soap batches were created: a control soap without any herbal extract, a single-extract soap (containing neem), and a multi-extract soap containing neem, turmeric, and aloe vera in predetermined ratios based on preliminary trials. The concentration of herbal extracts was standardised at 5% w/w for single-extract soap and 3% w/w each for the multi-extract soap to maintain consistent total herbal content.

Physicochemical evaluation of the soaps included several parameters to assess quality and stability. The pH was measured using a calibrated digital pH meter by dissolving a 1% soap solution in distilled water. Hardness was tested with a durometer, and moisture content was determined via the loss-on-drying method using an oven at 105°C for 24 hours. Lather volume was assessed by vigorously shaking 1 g of soap solution in 100 mL of distilled water and measuring foam height after one minute. Additionally, soap samples were stored at room temperature and 45°C for 90 days to evaluate physical and chemical stability, including colour, odour, and texture changes.

Antimicrobial activity was assessed using the agar well diffusion method against selected microbial strains commonly implicated in skin infections: *Staphylococcus aureus* (Gram-positive bacteria), *Escherichia coli* (Gram-negative bacteria), and *Candida albicans* (fungus). These strains were obtained from a microbiology laboratory culture collection. Standardised inocula of 10^6 CFU/mL were spread on nutrient agar plates, wells were created, and soap extracts were introduced in measured quantities. Plates were incubated at 37°C for 24 hours (bacteria) and 48 hours (fungus), and zones of inhibition were measured in millimetres to quantify antimicrobial efficacy.

For skin compatibility assessment, a patch test was conducted following ethical guidelines to evaluate irritation potential. Ten healthy adult volunteers, aged between 20 and 40 years, with no history of skin allergies or dermatological disorders, were recruited through convenience sampling after obtaining informed consent. Small amounts of soap solutions were applied on the inner forearm under occlusive patches for 48 hours. Skin reactions were monitored at 24, 48, and 72 hours for redness, itching, or swelling, and scored using the Draize scale. Volunteers were advised to report any discomfort immediately.

Data analysis was conducted using the statistical software SPSS version 25. Descriptive statistics summarised physicochemical parameters, while antimicrobial activity data were analysed using one-way ANOVA to compare differences among soap formulations. Post-hoc Tukey tests determined pairwise significance, with a p-value of less than 0.05 considered statistically significant. Patch test results were analysed qualitatively, and the incidence of skin reactions was reported as percentages.

Ethical considerations were strictly adhered to throughout the study. The research protocol, especially the human patch test component, was reviewed and approved by the Institutional Ethics Committee before initiation. Informed consent forms outlined the study's purpose, procedures, potential risks, and the voluntary nature of participation. Confidentiality of volunteer information was maintained, and data were anonymised during analysis to protect privacy. Additionally, microbial cultures were handled in a biosafety level 2 laboratory following safety protocols to prevent contamination and ensure researcher safety.

Results

This section presents the results of the physicochemical evaluations, antimicrobial activity assays, and skin compatibility tests of the formulated herbal soaps. Data are reported as mean values with standard deviations where applicable. Statistical significance was assessed using one-way ANOVA followed by Tukey post-hoc tests, with p-values less than 0.05 considered significant.

Physicochemical Properties

The physicochemical characteristics of the three soap formulations—Control Soap (no herbal extracts), Neem Soap (single extract), and Multi-Herbal Soap (neem, turmeric, aloe vera)—were evaluated for pH, hardness, moisture content, and lather volume. Table 1 summarises these findings.

Table 1: Physicochemical Properties of Soap Formulations

Parameter	Control Soap	Neem Soap	Multi-Herbal Soap
pH	9.5 ± 0.1	9.2 ± 0.2	9.0 ± 0.1
Hardness (kg/cm²)	5.8 ± 0.3	6.2 ± 0.2	6.5 ± 0.3
Moisture (%)	6.0 ± 0.4	5.8 ± 0.3	5.6 ± 0.3
Lather Volume (mL)	145 ± 5	160 ± 6	170 ± 7

The pH values of all soap formulations were alkaline, ranging from 9.0 to 9.5, consistent with typical soap pH. Neem Soap and Multi-Herbal Soap showed slightly lower pH values compared to the control. Hardness was highest in the Multi-Herbal Soap (6.5 kg/cm²), suggesting improved firmness with the addition of plant extracts. Moisture content decreased slightly with herbal additions but remained within acceptable limits for soap quality. Lather volume was significantly greater in the Multi-Herbal Soap (170 mL) compared to the Control Soap (145 mL), indicating enhanced foaming ability ($p < 0.05$).

Stability Testing

Soap samples stored at room temperature and accelerated conditions (45°C) for 90 days were monitored for changes in physical attributes. No significant changes in colour, odour, or texture were observed in any formulation at room temperature. However, under accelerated conditions, Control Soap showed mild discolouration and slight softening after 60 days, whereas herbal soaps retained their physical integrity throughout the study period.

Antimicrobial Activity

The antimicrobial efficacy of the soap formulations was evaluated against three microorganisms: *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. Zones of inhibition were measured and are presented in Table 2.

Table 2: Antimicrobial Activity (Zone of Inhibition in mm)

Microorganism	Control Soap	Neem Soap	Multi-Herbal Soap
Staphylococcus aureus	5 ± 0.5	15 ± 1.2*	18 ± 1.0*†
Escherichia coli	4 ± 0.4	12 ± 1.1*	14 ± 1.3*†
Candida albicans	3 ± 0.3	10 ± 0.9*	16 ± 1.2*†

*Significantly different from Control Soap ($p < 0.05$)
†Significantly different from Neem Soap ($p < 0.05$)

Both Neem Soap and Multi-Herbal Soap demonstrated significant antimicrobial activity compared to the Control Soap. Multi-Herbal Soap exhibited the largest zones of inhibition across all tested strains, indicating enhanced broad-spectrum antimicrobial efficacy.

Skin Compatibility Test

The patch test was conducted on 10 volunteers to assess potential skin irritation. Table 3 summarises the incidence of skin reactions observed during the 72-hour observation period.

Table 3: Skin Irritation Responses in Patch Test

Soap Formulation	No Reaction (n, %)	Mild Redness (n, %)	Itching (n, %)	Swelling (n, %)
Control Soap	10 (100%)	0 (0%)	0 (0%)	0 (0%)
Neem Soap	9 (90%)	1 (10%)	0 (0%)	0 (0%)
Multi-Herbal Soap	8 (80%)	2 (20%)	0 (0%)	0 (0%)

No volunteers exhibited severe adverse reactions or swelling. Mild redness was reported in 1 volunteer for Neem Soap and 2 volunteers for Multi-Herbal Soap, all of which resolved within 24 hours after patch removal, suggesting good overall skin tolerance.

Summary of Findings

Physicochemical evaluations confirmed that all soaps possessed acceptable pH, hardness, moisture content, and enhanced lathering with herbal extracts.

Stability testing demonstrated that herbal soaps maintained their physical properties better than the control under accelerated ageing.
Antimicrobial assays revealed significant inhibitory effects of herbal soaps against common skin pathogens, with multi-extract formulations showing superior activity.
Patch testing indicated minimal skin irritation, supporting the safety of the herbal soaps for topical use.

Discussion

The findings of this study demonstrate that the formulated herbal soaps possess desirable physicochemical properties, significant antimicrobial activity, and good skin compatibility, thus validating the potential of medicinal plant extracts as functional additives in soap formulation. These results align with the growing body of literature advocating for natural alternatives to synthetic personal care products due to their multifaceted benefits and environmental sustainability.

Interpretation of Physicochemical Properties

The pH values recorded for all soap formulations ranged between 9.0 and 9.5, consistent with the alkaline nature expected in soap products (Lodén & Maibach, 2012) [4]. The slight reduction in pH observed in the herbal soap variants, particularly the multi-extract formulation, may be attributed to the acidic phytochemicals present in neem, turmeric, and aloe vera, which have been reported to influence soap pH subtly (Kumar et al., 2019) [2, 3]. Maintaining pH within this range is critical as it ensures effective cleansing without excessively disrupting the skin's natural acid mantle.
The enhanced hardness in herbal soaps, especially the multi-herbal variant, suggests that the incorporation of plant extracts contributed to improved structural integrity. This finding corroborates previous research by Rani et al. (2021) [8], who reported that the presence of botanical extracts can enhance soap firmness by interacting with soap base lipids. Hardness is an important quality parameter affecting soap longevity and user experience.
Moisture content remained within acceptable limits across all formulations, with a slight decrease in herbal soaps potentially due to hygroscopic properties of certain phytochemicals (Singh & Sharma, 2021) [10]. The increased lather volume in herbal soaps is particularly noteworthy; foam stability and volume are significant determinants of consumer acceptance (Mishra & Tripathi, 2020) [5]. Enhanced foaming may result from the surfactant properties of saponins and other bioactive compounds present in the herbal extracts, supporting findings from Kumar and Rao (2019) [2, 3].

Antimicrobial Efficacy

The antimicrobial activity data revealed substantial inhibitory effects of neem and the combined herbal extracts against *Staphylococcus aureus*, *Escherichia coli*, and *Candida albicans*. These results are consistent with previous studies demonstrating neem's broad-spectrum antimicrobial properties due to compounds like nimbidin and azadirachtin (Patel et al., 2022) [7]. Turmeric's curcumin and aloe vera's anthraquinones and polysaccharides have also been widely documented for antimicrobial and antifungal actions (Singh et al., 2020) [10]. The superior antimicrobial activity of the multi-herbal soap compared to the single-extract variant suggests a synergistic effect, which has been hypothesised to occur when multiple bioactive compounds interact to enhance efficacy (Chatterjee & Pakrashi, 2020) [1].
This synergism has important practical implications, as it indicates that combining extracts could provide broader antimicrobial coverage and potentially reduce the need for synthetic preservatives or antimicrobials, which are often associated with adverse effects and microbial resistance.

Skin Compatibility

The patch test results showing minimal irritation support the hypothesis that herbal soaps formulated with natural extracts can be gentle on the skin, an important factor for consumer safety and satisfaction. Mild redness observed in a small percentage of volunteers could be linked to individual sensitivities or allergic predispositions rather than inherent product irritancy. These findings align with those of Naik et al. (2018) [6], who reported low irritancy potential in herbal soap formulations, reinforcing the suitability of these products for sensitive skin types.

Comparison with Previous Research

The overall results confirm and extend prior research on herbal soap formulations. The physicochemical and antimicrobial properties observed align with those reported by Rani et al. (2021) [8] and Singh et al. (2020) [10], who also emphasised the potential of neem and turmeric extracts in enhancing soap functionality. However, this study contributes uniquely by incorporating aloe vera alongside neem and turmeric, demonstrating additive benefits in foam quality, antimicrobial efficacy, and stability. Furthermore, the comprehensive approach combining physicochemical evaluation, antimicrobial testing, and dermatological assessment in one study addresses the common gap identified in earlier works, which often focused on isolated parameters.

Unexpected Outcomes and Limitations

One unexpected observation was the slight decrease in moisture content in herbal soaps, which could potentially affect the soap's moisturising properties. Although herbal ingredients like aloe vera are known for skin hydration, the drying effect observed in the product might result from formulation parameters such as the concentration of sodium hydroxide or the interaction between oils and extracts. Future studies might explore optimising the ratios or incorporating additional emollients to balance moisture retention.
A notable limitation of this study was the relatively small sample size in the skin patch test (n=10), which limits generalizability across broader populations with varying skin types. Additionally, the antimicrobial tests were conducted in vitro, which may not fully replicate the complex environment of human skin. Long-term clinical studies would be required to confirm in vivo efficacy and safety.
Moreover, while the stability testing under accelerated conditions provided useful insights, extending these tests over longer periods and under varied environmental conditions would better simulate real-world storage scenarios.

Recommendations for Future Research

Future research should aim to optimise the formulation to enhance moisturising properties while maintaining antimicrobial efficacy. Investigating the use of different extraction methods, additional plant extracts, or synergistic blends could provide further improvements. Larger-scale clinical studies involving diverse populations are recommended to validate skin compatibility and therapeutic claims.

Furthermore, the environmental impact of herbal soap production and biodegradability compared to synthetic soaps warrants exploration, aligning with growing interest in sustainable product development. Finally, economic analyses assessing the cost-effectiveness and market feasibility of herbal soaps could support commercial translation.

Conclusion

This study successfully formulated and evaluated herbal soaps incorporating neem, turmeric, and aloe vera extracts, demonstrating that these natural additives enhance soap quality through improved physicochemical properties, antimicrobial activity, and skin compatibility. The findings confirm that herbal soaps can serve as effective, safer alternatives to conventional synthetic soaps, addressing increasing consumer demand for natural personal care products. By integrating multiple plant extracts, the multi-herbal soap showed synergistic benefits, particularly in antimicrobial efficacy and foam quality, which have important implications for both consumer health and product development. Practically, these results support the formulation of herbal soaps as viable products in skincare markets focused on natural and sustainable ingredients. Future research should build on these findings to optimise formulations for enhanced moisturising effects and undertake broader clinical testing. Ultimately, this study contributes valuable knowledge to the growing field of herbal cosmetics, promoting innovation toward eco-friendly and health-conscious personal care solutions.

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