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Formulation and Evaluation of Polyherbal Soap with Antibacterial and Dermatological Benefits: A Polymer Chemistry Approach

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Abstract

This study investigates the formulation and evaluation of polyherbal soap composed of extracts from Vitex negundo, Azadirachta indica, and Curcuma longa. These plants possess significant antibacterial, dermatological, and skin-nourishing properties. The soap formulation follows a saponification process using coconut oil and sodium hydroxide as primary reactants, incorporating polymer chemistry principles in soap structuring and stability. Polymers such as polysaccharides and fatty acid chains contribute to the stability, viscosity, and foaming properties of the soap, ensuring better emulsification of herbal extracts. Physicochemical parameters, including pH, foam height, and antimicrobial efficacy, were assessed to determine the formulation's effectiveness. The formulated soap demonstrated excellent antibacterial activity against Escherichia coli and Staphylococcus aureus, with inhibition zones of 16 mm and 11 mm, respectively. Additionally, polymeric surfactants were observed to enhance the retention of bioactive compounds, ensuring prolonged antimicrobial efficacy. The structural characteristics of the polymeric matrix also improved the soap's hydration properties, making it more suitable for skin nourishment. The findings suggest that polyherbal soap is a viable natural alternative for skincare, offering protective and therapeutic benefits while leveraging polymeric interactions to enhance soap performance. The integration of polymer chemistry into herbal soap formulations presents an innovative approach to improving product quality, stability, and efficiency in personal care applications.

Keywords: Polyherbal soap, antibacterial activity, saponification, polymer chemistry, skin nourishment

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INTRODUCTION

Synthetic soaps often contain harsh chemicals that can lead to skin irritation, dehydration, and potential long-term dermatological damage. The rise in awareness regarding natural skincare solutions has led to increased interest in herbal-based soap formulations.[1] Herbal soaps provide a viable alternative due to their mild nature and therapeutic properties derived from medicinal plant extracts.

Among the various plant-based ingredients, Vitex negundo, Azadirachta indica (neem), and Curcuma longa (turmeric) have been extensively studied for their remarkable antibacterial, anti-inflammatory, and dermatological benefits.[2] Vitex negundo is known for its analgesic, antihistamine, and antimicrobial properties, making it suitable for soothing skin ailments. Azadirachta indica possesses potent antibacterial and antifungal activity, helping to combat skin infections, acne, and irritation.[3] Curcuma longa, rich in curcuminoids, acts as a strong antioxidant and anti-inflammatory agent, promoting skin rejuvenation and healing.

Polymer chemistry plays a crucial role in the formulation of herbal soaps, particularly in the stabilization of bioactive compounds, the formation of micelles, and the enhancement of foam and emulsification properties. Polymers such as polysaccharides and surfactants improve the binding efficiency of active ingredients, ensuring their uniform dispersion within the soap matrix and prolonged activity on the skin. The interaction between fatty acids, alkali, and herbal extracts in a polymeric network contributes to the structural integrity and overall effectiveness of the soap [4].

This research aims to develop a polyherbal soap that incorporates these extracts, leveraging polymer chemistry principles to optimize its physicochemical properties and antimicrobial potential. The study evaluates the formulation's effectiveness by analyzing parameters such as pH, foam stability, bioactive retention, and bacterial inhibition. By integrating polymeric interactions into herbal soap production, this study contributes to advancing natural skincare solutions with enhanced efficacy and stability.

Despite the availability of many herbal soap products, very few combine polymer chemistry with multi-herbal formulations specifically targeted at both antibacterial and dermatological performance. Most commercial herbal soaps focus on one or two plant extracts without optimized delivery or stabilization strategies. This study addresses that gap by formulating a polyherbal soap incorporating *Vitex negundo*, *Azadirachta indica*, and *Curcuma longa* within a polymer-stabilized soap matrix, aiming to enhance both bioactivity and shelf-life. The conceptualization of this work stems from the observed limitations in current herbal soaps, particularly regarding the poor retention of bioactive ingredients, instability under varied conditions, and lack of standardized antibacterial performance. The goal was to apply polymer chemistry principles to overcome these issues and create a stable, multifunctional herbal soap.

Unlike most commercial products that rely on individual herbal extracts, this formulation combines three botanicals known for complementary antibacterial and dermatological benefits. Furthermore, the application of polymer chemistry allows better emulsification and prolonged bioactivity, which is not commonly addressed in existing formulations. Thus, this approach offers a scientifically driven improvement over current herbal soap.

MATERIALS AND METHODS

This section outlines the materials, methods, and polymeric principles involved in the formulation of polyherbal soap. The process includes ingredient selection, polymeric interactions, extraction techniques, and physicochemical characterization, ensuring stability and efficacy in personal care applications.

Role of Polymer Chemistry in Soap Formulation

Polymer chemistry plays a crucial role in stabilizing the structure and improving the efficacy of herbal soap formulations.[5] The presence of polymeric substances such as natural polysaccharides, fatty acid chains, and surfactants enhances the binding capacity of active herbal components, allowing for better dispersion and prolonged skin contact time. These polymers also contribute to the viscosity, foam stability, and emulsification properties of the soap, ensuring a consistent texture and enhanced cleansing ability.

In herbal soap formulations, biopolymeric compounds derived from plant extracts function as natural thickeners, emulsifiers, and stabilizers.[6] Polysaccharides such as pectin and cellulose increase the retention of bioactive ingredients, preventing their degradation and extending the soap's shelf life. Additionally, surfactants formed during the saponification process interact with fatty acid chains, creating micellar structures that enhance the soap's solubility and improve the delivery of herbal constituents to the skin.

Furthermore, polymeric networks within the soap matrix aid in moisture retention, reducing the drying effects typically associated with conventional soaps. These polymer interactions ensure that essential oils and herbal extracts remain bioavailable, promoting skin nourishment and therapeutic benefits. The integration of polymer chemistry principles in herbal soap formulation, therefore, enhances not only the structural integrity of the soap but also its effectiveness in delivering antibacterial and dermatological benefits to the user.

Preparation of Herbal Extracts

The preparation of herbal extracts involves different extraction techniques to ensure the maximum retention of bioactive compounds, which contribute to the therapeutic properties of the soap.[7] Each plant extract is obtained through specific methods optimized for efficiency and stability.

Vitex negundo Extract

The maceration method is employed, where 5 g of dried Vitex negundo leaves are soaked in 50 ml of methanol (solvent:drug ratio = 10:1) for 24 hours at room temperature with occasional stirring to ensure uniform extraction. After the soaking period, the mixture is subjected to sonication for 30 minutes to enhance the release of bioactive compounds. The solution is then filtered using Whatman No. 1 filter paper, and the solvent is evaporated under reduced pressure at 40°C using a rotary evaporator to prevent the degradation of heat-sensitive phytochemicals. The resulting concentrated extract is stored in an amber-colored glass bottle at 4°C to maintain stability and bioactivity until further use in soap formulation [8].

Azadirachta indica Extract

The decoction method is used, wherein 9 g of powdered Azadirachta indica leaves are boiled in 100 ml of distilled water for four hours with occasional agitation to facilitate the extraction of bioactive compounds. After boiling, the extract is allowed to cool to room temperature and then filtered using a fine muslin cloth followed by filtration through Whatman No. 1 filter paper to remove residual plant material. The filtrate is transferred to a rotary evaporator and concentrated at a controlled temperature of 50°C to prevent thermal degradation of active compounds. The concentrated extract is then stored in an amber-colored glass container at 4°C to protect it from light and maintain stability for future use in the soap formulation.

Curcuma longa Extract

The turmeric extract is prepared by dissolving 12 g of powdered Curcuma longa in 60 ml of distilled water. The mixture is subjected to a rotary shaker at 120 rpm for 10 hours and 30 minutes to facilitate the extraction of curcuminoids and essential bioactive compounds. After extraction, the mixture is filtered using a fine muslin cloth followed by filtration through Whatman No. 1 filter paper to remove residual solid particles. The filtrate is then concentrated using a rotary evaporator at a controlled temperature of 45°C to preserve the stability of heat-sensitive compounds. The resulting concentrated extract is stored in an amber-colored glass container at 4°C to prevent degradation due to light exposure and oxidation.[9] This optimized extraction process ensures a high yield of active ingredients, maximizing the therapeutic potential of the extract in the soap formulation.

Soap Base Preparation

The soap base was prepared using a saponification reaction involving triglycerides from coconut oil (30 ml) and sodium hydroxide (15.7 g) as the primary reactants.[10] To facilitate the reaction and improve homogeneity, ethyl alcohol (2 ml) was added as a co-solvent, and distilled water (10 ml) was incorporated to maintain the reaction medium.

The mixture was stirred continuously at a controlled temperature of 60°C to ensure complete saponification. The reaction was monitored by checking the disappearance of oil droplets and the formation of a uniform, viscous mixture. Once saponification was complete, the soap base was subjected to purification using salt and acid washing to remove any excess alkali and unreacted fatty acids, thereby improving the soap's quality and stability.

The purified soap base was then allowed to cool gradually to room temperature to prevent premature crystallization and enhance the polymeric interactions within the soap matrix. The resulting solidified soap base exhibited improved texture, structural integrity, and uniformity, ensuring an optimal foundation for the subsequent incorporation of herbal extracts.

Polyherbal Soap Formulation

The prepared soap base (125 g) was combined with herbal extracts in the following proportions to enhance its antimicrobial, moisturizing, and dermatological benefits. The selected extracts were meticulously incorporated to optimize both stability and efficacy in skin care applications:

- *Vitex negundo extract:* 2 ml, known for its analgesic and antimicrobial properties, helping in soothing skin irritation and inflammation [11].
- *Azadirachta indica extract:* 1.5 ml, widely recognized for its antibacterial and antifungal properties, providing protection against skin infections and acne.
- *Curcuma longa extract:* 2.5 ml, a potent anti-inflammatory agent, contributing to skin rejuvenation and healing.
- *Almond oil:* 4 ml, incorporated to enhance the soap's emollient properties, ensuring hydration and preventing skin dryness [12].

To achieve a uniform dispersion of these active ingredients, the soap base was first melted at a controlled temperature of 55°C. The extracts were gradually introduced while stirring continuously for 30 minutes to maintain homogeneity and prevent phase separation. The well-mixed formulation was then poured into pre-sanitized molds and allowed to cool at room temperature for 24 hours to ensure proper solidification and polymeric stabilization. This process enhances the polymeric interactions between fatty acids and herbal bioactives, improving the soap's consistency, durability, and skin adherence.

Herbal-derived foaming agents such as *Sapindus mukorossi* (soapnut) or *Shikakai* were considered; however, to maintain formulation standardization and focus on polymeric structuring, the present study employed traditional saponification-derived surfactants. Future studies may integrate natural foaming agents for comparative evaluation.

EVALUATION OF PHYSICOCHEMICAL PROPERTIES

Organoleptic Properties

The organoleptic properties, including color, odor, texture, and general appearance, were visually and manually assessed.[13] The formulated polyherbal soap was observed to have a greenish hue due to the presence of herbal extracts. It exhibited an aromatic scent derived from the essential oils and plant bio actives. The texture was smooth and uniform, indicating good emulsification and homogeneity in the formulation.

pH Determination

The pH of the polyherbal soap was measured using a digital pH meter to ensure skin compatibility. A sample of the soap was dissolved in distilled water, and the pH was recorded. The formulated soap had a pH of 8, which is suitable for maintaining the skin's natural moisture balance while preventing excessive dryness or irritation [14].

Foam Height and Retention

Foamability and foam stability are crucial factors in determining cleansing efficacy.[15] Foam height was measured by dissolving 0.5 g of soap in 50 ml of distilled water in a graduated cylinder, followed by vigorous shaking. The foam height was recorded immediately and again at regular intervals to determine foam retention. The soap exhibited a foam height of 10 cm, which was retained for approximately 3 minutes, indicating effective surfactant activity and polymeric stabilization of foaming agents.

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Alcohol Insoluble Matter

Alcohol insoluble matter was determined by dissolving 5 g of soap in warm ethanol, filtering, drying at 105°C, and weighing the residue.[16] This parameter helps assess the purity and presence of unreacted fatty acids, ensuring a high-quality soap product. The formulated polyherbal soap contained 16% alcohol-insoluble matter, signifying a well-saponified and stable composition.

Moisture Content and Hardness

Moisture content is an essential parameter that affects the hardness and longevity of the soap. Excess moisture can lead to rapid dissolution, while insufficient moisture can make the soap brittle.[17] The moisture content was measured using a gravimetric method, and the soap was found to have an optimal moisture balance that provided a firm yet easily lathering texture. Hardness was assessed manually and found to be consistent with commercial herbal soap standards.

Stability Testing

Stability tests were conducted to evaluate the longevity and shelf-life of the formulated soap. [18] Samples were stored under varying temperature conditions (room temperature, refrigeration, and accelerated conditions at 40°C) for 30 days. The formulation retained its color, texture, and pH without significant changes, demonstrating good stability and resistance to environmental factors.

The comprehensive evaluation of physicochemical properties confirms that the polyherbal soap exhibits desirable characteristics in terms of stability, lathering ability, pH balance, and structural integrity.[19] These findings highlight the benefits of polymer-enhanced herbal formulations in delivering effective and stable personal care products.

ANTIMICROBIAL TESTING

The antimicrobial activity was assessed using the bore diffusion method against *Escherichia coli* and *Staphylococcus aureus*.[20] A 1% soap solution was prepared and applied to agar plates, followed by incubation at 37°C for 24 hours. Ciprofloxacin (5 µg/disc) was used as a positive control. Figure 1 shows Zone of Inhibition a) E Coli b) S. aureus.

DISCUSSION

The discussion section analyzes the effectiveness of the polyherbal soap in terms of its physicochemical properties, polymer chemistry contributions, and antimicrobial activity. The results obtained are compared with existing commercial formulations and previous studies to assess the advantages of incorporating herbal extracts into soap formulations.

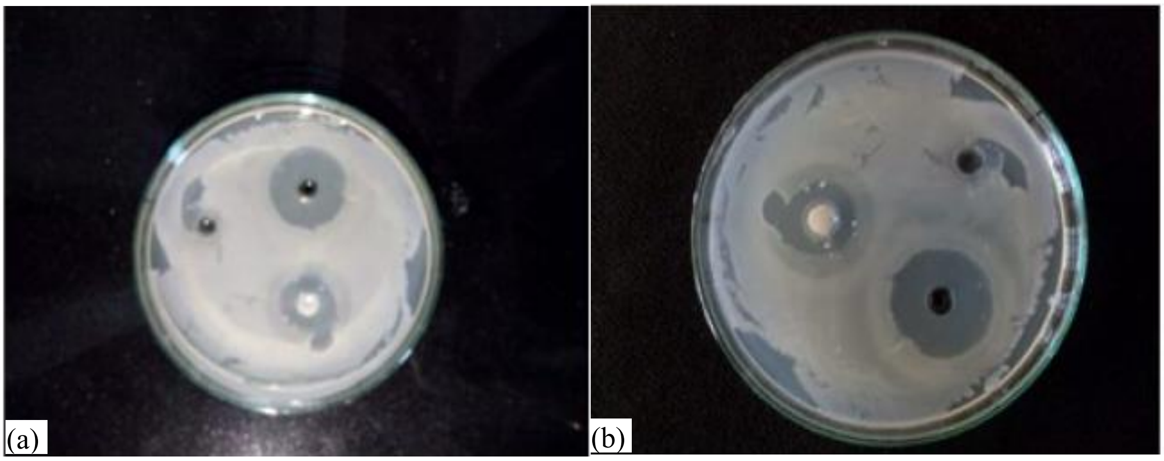

Figure 1. Zone of Inhibition a) E Coli b) S. aureus.

Physicochemical and Polymer Chemistry Aspects

The formulated soap exhibited desirable characteristics, including a pH of 8, foam height of 10 cm, foam retention of 3 minutes, and alcohol-insoluble matter of 16%. [21] The soap had a greenish color, aromatic odor, and smooth texture. The incorporation of polymeric interactions within the fatty acid matrix improved foam stability, texture uniformity, and hydration retention [22].

Antimicrobial Activity

The formulated soap demonstrated significant antibacterial activity, with inhibition zones of 16 mm for *E. coli* and 11 mm for *S. aureus*. These results indicate that the polyherbal soap effectively inhibits bacterial growth, surpassing the activity of individual plant extracts. The presence of polymeric substances in the herbal formulation enhanced active ingredient retention, improving long-term antibacterial performance [23].

Use of Foaming Agents

While synthetic surfactants formed during saponification provided satisfactory foam stability, the incorporation of herbal foaming agents remains a promising future direction. Natural saponins from *Sapindus* or *Glycyrrhiza glabra* could further enhance the eco-friendliness and marketing appeal of the formulation.

CONCLUSION

The formulated polyherbal soap showed promising results in terms of physicochemical properties, polymeric interactions, and antibacterial activity. The combination of *Vitex negundo*, *Azadirachta indica*, and *Curcuma longa* provides enhanced antimicrobial and dermatological benefits. The polymer chemistry principles applied in this study played a crucial role in improving soap texture, stability, and active ingredient delivery. This formulation offers a natural, effective alternative for skincare, emphasizing the importance of polymer-based enhancements in herbal personal care products. The antimicrobial studies revealed that the formulated polyherbal soap exhibited strong activity against *Escherichia coli* and *Staphylococcus aureus*, with inhibition zones of 16 mm and 11 mm, respectively. These findings underscore the potential of herbal formulations in offering natural alternatives to synthetic antibacterial soaps. Furthermore, physicochemical evaluations confirmed the soap’s desirable properties, including optimal pH balance, good lathering ability, and enhanced stability under various storage conditions. These characteristics make it suitable for regular use, catering to consumers seeking effective, natural skincare solutions. Overall, this study highlights the importance of integrating polymer chemistry with herbal formulations to create stable, high-performance personal care products. Future research can explore additional plant extracts and polymeric modifications to further optimize the efficacy and shelf-life of herbal soaps.

REFERENCES

1. Konaparthi SB, Guduru MR, Anumalasetti A, Kakad K, Nawale S. Herbal Nanocosmeceuticals: The Ultimate Fusion of Science and Nature. Pharmacophore. 2024;15(5-2024):1-4.
2. Aladejana EB, Adelabu OA, Aladejana AE, Ndlovu SI. Antimicrobial properties of alternative medicines used in the management of infections in diabetic patients: A comprehensive review. Pharmacological research-modern Chinese medicine. 2024 Jun 1;11:100432.
3. Ni Putu Ratna K, Afifah FN, Kartika T, Prianto AH. Neem Oil (Azadirachta indica A. juss) as a Potential Natural Active Compound in Cosmetic Properties Title. Biomass-based Cosmetics: Research Trends and Future Outlook. 2024 Jun 30:325-50.
4. KADER N, ACARALI N. Optimizing Soap Formulas With Design-Expert by Using Pomegranate Seed (Punica Granatum) and Licorice (Glycyrrhiza Glabra) as Natural Additives Based on Green Chemistry. Journal of Cosmetic Science. 2024 May 1;75(3).
5. Meftahi A, Samyn P, Geravand SA, Khajavi R, Alibkhshi S, Bechelany M, Barhoum A. Nanocelluloses as skin biocompatible materials for skincare, cosmetics, and healthcare:

Formulations, regulations, and emerging applications. Carbohydrate Polymers. 2022 Feb 15;278:118956.
6. Mendoza-Muñoz N, Leyva-Gómez G, Piñón-Segundo E, Zambrano-Zaragoza ML, Quintanar-Guerrero D, Del Prado Audelo ML, Urbán-Morlán Z. Trends in biopolymer science applied to cosmetics. International Journal of Cosmetic Science. 2023 Dec;45(6):699-724.
7. Debnath A, Das A. Isolation of bioactive compounds from low-cost agricultural resources and its utilization in daily life. Access Microbiology. 2024 Jun 1;6(6):000660-v4.
8. Maheshwaran L, Nadarajah L, Senadeera SP, Ranaweera CB, Chandana AK, Pathirana RN. Phytochemical Testing Methodologies and Principles for Preliminary Screening/Qualitative Testing. Asian Plant Research Journal. 2024 Aug 19;12(5):11-38.
9. Tripathi S, Kumar L, Deshmukh RK, Gaikwad KK. Ultraviolet blocking films for food packaging applications. Food and Bioprocess Technology. 2024 Jun;17(6):1563-82.
10. Yuan W, Yang F. Chemical conversion process for biodiesel production. InBiomass to Renewable Energy Processes 2017 Oct 5 (pp. 299-374). CRC Press.
11. Khan SZ, Hazrat A, Khan FA, Yahya M, Rahim G, Mukhtiar M, Khan MA, Ullah H. Assessment of Phytochemical Profiling and Therapeutic Potential of the Ethanolic Extract of Vitex negundo (L.). Sarhad Journal of Agriculture. 2024 Jun 1;40(2):395-406.
12. Vishali S, Kavitha E, Selvalakshmi S. Therapeutic Role of Essential Oils. Essential Oils: Extraction Methods and Applications. 2023 Jul 14:953-76.
13. Özdoğan G, Lin X, Sun DW. Rapid and noninvasive sensory analyses of food products by hyperspectral imaging: Recent application developments. Trends in Food Science & Technology. 2021 May 1;111:151-65.
14. Arun SK. FORMULATION AND EVALUATION OF HERBAL SOAP. World Journal of Pharmaceutical Research. 2023 Apr 10;12(9):2136-47.
15. Bogdan C, Safta DA, Iurian S, Petrușcă DR, Moldovan ML. QbD Approach in Cosmetic Cleansers Research: The Development of a Moisturizing Cleansing Foam Focusing on Thickener, Surfactants, and Polyols Content. Gels. 2024 Jul 23;10(8):484.
16. Nnyia MO, Oladipo A, Anyaebosim EV, Ejeromedoghene O. The Preparation and Physicochemical Analysis of Local Black Soap from Coconut Oil and Plantain Peel Biochar. Journal of the Turkish Chemical Society Section A: Chemistry. 2023 Feb 2;10(1):177-84.
17. Appleton HA, Simmons WH. The handbook of soap manufacture. DigiCat; 2022 Sep 4.
18. Pranjali Pokharkar, Namrata Gaonkar, Shashikiran N.D., Sachin Gugawad, Swapnil Taur, Savita Hadakar. Qualitative and Quantitative Effects of Non-Thermal Atmospheric Pressure Plasma and ErCr: YSGG Laser Activation on Surface Remineralization and Fluoride Release of Three Different Fluoride Varnishes. Journal of Polymer and Composites. 2024; 12(05):292-303.
19. Sari RI, Rahmah AA, Hermansyah O, Rahmawati S. FORMULATION AND TESTING OF SOLID SOAP CONTAINING 96% ETHANOL EXTRACT OF PURSLANE (Portulaca oleracea L.) COMBINED WITH VIRGIN COCONUT OIL (VCO) AGAINST Staphylococcus aureus. Medical Sains: Jurnal Ilmiah Kefarmasian. 2024 Nov 21;9(4):927-34.
20. Dr. Pradnya Chaudhari, Dr. Shashikiran N.D, Dr. Sachin gugawad, Dr. Namrata Gaonkar, Dr. Swapnil Taur, Dr. Savita Hadakar. Comparative Assessment of Antibacterial Effectiveness, Bioactivity, Fluoride Release, and Microleakage of Various Bioactive Smart Composites: An In Vitro Investigation.. Journal of Polymer and Composites. 2024; 12(03):76-86.
21. Gubitosa J, Rizzi V, Fini P, Cosma P. Hair care cosmetics: From traditional shampoo to solid clay and herbal shampoo, a review. Cosmetics. 2019 Feb 19;6(1):13.
22. Padole N, Avari J. Synthesis of silver nanoparticles for antibacterial activity against Staphylococcus aureus and Escherichia coli. Asian Journal of Pharmaceutical Research and Development. 2021 Oct 15;9(5):67-73.
23. Das S, Agarwal S, Samanta S, Kumari M, Das R. Formulation and evaluation of herbal soap. J. Pharmacogn. Phytochem. 2024;13:14-9.

