



FORMULATION OF NATURAL PHYTO-FORMULATED SOAP FOR ENHANCED SKIN WELLNESS USING AZADIRACHTA INDICA (NEEM), CURCUMA LONGA (TURMERIC), AND OCIMUM SANCTUM (TULSI)

Gokul Gopalakrishnan^{1*}, Shashank MS², Chirag Aditya L³, Anjana Menon⁴

¹ Student, Garden City University Email id :- gokulkrishna3738@gmail.com

² Student, Garden City University

³ Student, Garden City University

⁴ Assistant professor of the Life Science Department of Garden City University

Corresponding author: Gokul Gopalakrishnan

Student, Garden City University Email id :- gokulkrishna3738@gmail.com

Abstract

Herbal soap formulations incorporating neem (*Azadirachta indica*), turmeric (*Curcuma longa*), and tulsi (*Ocimum sanctum*) offer a multifunctional approach to skin hygiene due to the presence of diverse bioactive phytochemicals with antimicrobial, anti-inflammatory, antioxidant, and skin-protective properties. Neem and tulsi contribute bioactive constituents such as nimbidin, azadirachtin, and eugenol, which exhibit broad-spectrum antimicrobial activity and aid in reducing inflammatory responses associated with skin irritation and microbial infections. Turmeric, rich in curcumin, provides additional antioxidant and anti-inflammatory support, contributing to wound healing and protection against oxidative stress induced by environmental factors such as ultraviolet radiation. When combined within a soap matrix, these botanicals demonstrate complementary and synergistic effects that enhance microbial control, support skin barrier function, and promote overall skin health during routine cleansing. The formulation utilizes skin-compatible base oils and appropriate soap-making methodologies to ensure product stability, safety, and suitability for regular topical use. This study presents the formulation and scientific basis of a polyherbal soap incorporating neem, turmeric, and tulsi, discusses formulation and manufacturing considerations, and evaluates efficacy based on antimicrobial performance and physicochemical quality parameters. Polyherbal soaps formulated with these medicinal plants represent a promising, eco-friendly alternative to synthetic antimicrobial soaps, aligning traditional medicinal knowledge with contemporary demands for safe, sustainable, and effective personal care products.

Keywords: Herbal soap; *Azadirachta indica* (Neem); *Curcuma longa* (Turmeric); *Ocimum sanctum* (Tulsi); Antimicrobial activity

1. Introduction

Soap remains a foundational component of personal hygiene and public health, contributing significantly to the prevention of infectious diseases through routine skin cleansing. Its primary function involves the mechanical detachment and removal of microorganisms, dirt, excess sebum, and environmental contaminants from the skin surface, thereby reducing microbial burden and interrupting pathogen transmission. The incorporation of antimicrobial agents into soap formulations

enhances this protective function by providing additional chemical inhibition of microbial growth, improving overall cleansing efficiency (Manalo et al., 2024). Despite their effectiveness, the extensive incorporation of synthetic antimicrobial compounds, particularly triclosan and triclocarban, has generated growing concern within scientific and regulatory communities. These agents exhibit environmental persistence, limited biodegradability, and bioaccumulative tendencies, resulting in ecological toxicity. More critically, their indiscriminate use has been associated with the emergence of antimicrobial resistance (AMR), disruption of the native skin microbiome, and potential endocrine-related effects (Carey & McNamara, 2015). Regulatory restrictions imposed in several regions underscore the urgency for safer, sustainable alternatives in personal care formulations (Halden, 2014).

In response to these challenges, herbal soaps have gained increasing scientific and commercial attention as biocompatible cleansing systems derived from medicinal plants. Plant-based formulations offer a convergence of antimicrobial efficacy, anti-inflammatory activity, antioxidant protection, and enhanced skin tolerance, while reducing dependence on synthetic chemical additives (Dreno et al., 2019). Their renewable origin and environmental compatibility further support their relevance within sustainable product development paradigms. Among medicinal plants investigated for dermatological applications, *Azadirachta indica* (neem), *Curcuma longa* (turmeric), and *Ocimum sanctum* (tulsi) hold prominent positions in traditional medicine systems, particularly Ayurveda. Neem contains bioactive constituents such as nimbidin and nimbolide that demonstrate broad-spectrum antimicrobial and wound-healing properties (Wylie & Merrell, 2022). Turmeric, rich in curcuminoids, exhibits potent anti-inflammatory and antioxidant activity, contributing to skin protection and repair. Tulsi provides antimicrobial, immunomodulatory, and skin-soothing effects, attributed to phytochemicals including eugenol and ursolic acid. Contemporary scientific investigations have substantiated these properties, reinforcing their relevance for topical and rinse-off dermatological formulations (Panda et al., 2022). The integration of neem, turmeric, and tulsi into soap formulations enables routine topical exposure to bioactive phytochemicals during daily hygiene practices, offering functional skin protection within a rinse-off system. Such formulations require careful consideration of saponification chemistry, phytochemical stability, and performance characteristics to ensure efficacy without compromising safety or sensory attributes. Recent studies indicate that appropriately formulated herbal soaps can retain significant antimicrobial efficacy despite the rinse-off nature of the product (Islas et al., 2020; Lakhanapuram et al., 2025). This review critically synthesizes available scientific evidence on the dermatological relevance of neem, turmeric, and tulsi, with a focused emphasis on their application in polyherbal soap formulations. The article further examines formulation strategies, manufacturing methodologies, efficacy evaluation, and product-oriented considerations, thereby supporting the development of safe, effective, and sustainable natural antimicrobial soaps suitable for modern cosmeceutical applications.

2. Scientific Basis of Neem, Tulsi, and Turmeric on Skin

2.1 *Azadirachta indica* (Neem)

Azadirachta indica (neem) constitutes one of the most extensively investigated medicinal plants for dermatological and antimicrobial applications, owing to its diverse phytochemical composition and long-standing therapeutic relevance (Subapriya & Nagini, 2015). Neem contains bioactive constituents such as azadirachtin, nimbin, nimbidin, nimbolide, and gedunin, which collectively confer broad-spectrum antimicrobial, anti-inflammatory, and wound-healing properties. These compounds exert antimicrobial effects primarily through disruption of microbial cell membrane integrity, increased membrane permeability, and inhibition of essential enzymatic and protein synthesis pathways, ultimately impairing microbial growth and survival (Alzohairy, 2016). Empirical studies have demonstrated neem's efficacy against Gram-positive bacteria including *Staphylococcus aureus*, Gram-negative bacteria such as *Escherichia coli* and *Pseudomonas aeruginosa*, and pathogenic fungi including *Candida albicans* (Alzohairy, 2016). The convergence of antimicrobial

potency and skin-protective activity underscores neem's suitability for incorporation into herbal soap formulations designed for routine hygiene and infection-prone skin.

2.2 *Curcuma longa* (Turmeric)

Curcuma longa (turmeric) is recognized as a rich source of antimicrobial and anti-inflammatory phytochemicals with well-established relevance in topical dermatological formulations. The biological activity of turmeric is largely attributed to curcuminoids, particularly curcumin, supported by volatile constituents such as ar-turmerone, α -turmerone, and zingiberene (Teow et al., 2016). Curcumin exerts antimicrobial action by disrupting bacterial cell membranes and fungal cell walls, leading to increased permeability, leakage of intracellular components, and cell lysis. In addition, curcumin effectively inhibits microbial biofilm formation, a critical virulence factor associated with enhanced microbial persistence and resistance (Tyagi et al., 2015). Antimicrobial efficacy has been documented against organisms such as *Staphylococcus aureus*, *Escherichia coli*, and *Bacillus subtilis*. The combined antimicrobial, antioxidant, and anti-inflammatory effects of turmeric enhance skin protection and tolerance, reinforcing its functional role in herbal soap formulations (Hewlings & Kalman, 2017).

2.3 *Ocimum sanctum* (Tulsi or Holy Basil)

Ocimum sanctum (tulsi or holy basil) is widely valued for its antimicrobial and skin-soothing properties, which have been substantiated through both traditional use and modern scientific investigation (Pattanayak et al., 2017). Tulsi contains bioactive constituents including eugenol, ursolic acid, carvacrol, linalool, and rosmarinic acid, which contribute to its antimicrobial efficacy. The primary mechanism of action involves protein denaturation and disruption of the cytoplasmic membrane of microorganisms, resulting in compromised cellular integrity and metabolic dysfunction (Marchese et al., 2016). Tulsi extracts have demonstrated inhibitory activity against a broad range of bacterial and fungal pathogens relevant to skin infections. (Jamshidi & Cohen, 2017). In addition to antimicrobial action, tulsi exhibits anti-inflammatory and anti-acne properties that support skin comfort and barrier maintenance, making it a valuable component of herbal soap formulations intended for sensitive and acne-prone skin (Table 1).

Table 1. Key bioactive compounds and dermatological relevance of neem, turmeric, and tulsi

Plant source	Major bioactive compounds	Primary antimicrobial / skin-relevant actions	Relevance in soap formulation
<i>Azadirachta indica</i> (Neem)	Azadirachtin, nimbidin, nimbolide	Disruption of microbial membranes, inhibition of bacterial growth	Broad-spectrum antimicrobial support
<i>Curcuma longa</i> (Turmeric)	Curcumin, ar-turmerone	Anti-inflammatory, antioxidant, antibiofilm activity	Skin protection and irritation reduction
<i>Ocimum sanctum</i> (Tulsi)	Eugenol, ursolic acid	Antimicrobial, anti-acne, skin-soothing effects	Enhances antimicrobial efficacy and sensory comfort

(Source: Pattanayak et al., 2017)

3. Formulation of soap and manufacturing process



The successful integration of medicinal herbs into soap formulations requires a scientifically guided manufacturing approach that ensures preservation of bioactive constituents while maintaining physicochemical stability and functional performance. Herbal components are inherently sensitive to factors such as heat, pH, and oxidation; therefore, formulation strategies must balance effective saponification with the retention of antimicrobial activity (Hoang, Moon, & Lee, 2021). Careful selection of raw materials, processing conditions, and incorporation stages is essential to achieve a uniform, stable, and efficacious polyherbal soap suitable for routine dermatological use (Figure 1).





Figure1: Raw plant materials used for polyherbal soap formulation

The selection and preparation of herbal materials represent a critical determinant of the quality and efficacy of polyherbal soap formulations, as both the form and processing of plant materials influence phytochemical availability and stability. Neem is most effectively incorporated using finely powdered dried leaves and cold-pressed neem oil, the latter being particularly rich in limonoids and other bioactive constituents that readily disperse within the lipid phase of the soap base without significant degradation. For turmeric, although fresh rhizomes may be converted into a paste, dried turmeric powder is preferred due to its enhanced stability, ease of standardization, and consistent curcuminoid content; to avoid excessive skin staining and ensure acceptable sensory characteristics, turmeric is typically incorporated at controlled concentrations, commonly 1–2% of the total oil weight. Tulsi may be incorporated in the form of dried leaf powder or as an essential oil, both of which retain antimicrobial potency; however, the essential oil provides a more concentrated and uniform source of bioactive compounds while imparting a mild herbal fragrance that enhances consumer acceptability. Prior to drying, freshly collected neem and tulsi leaves are thoroughly washed with water to remove adhering soil, dust, and other contaminants (**Figure 2**).





Figure 2: Washing and cleaning of herbal materials prior to drying.

The cleaned plant materials are then subjected to controlled shade-drying to minimize thermal and photo-degradation of phytochemicals, followed by pulverization to obtain fine herbal powders suitable for formulation (Figure 3).



Figure 3: Drying and pulverization of herbal materials

The resulting dried powders are subsequently weighed and standardized to ensure batch-to-batch consistency and reproducibility of the polyherbal soap formulation (Figure 4).



Figure 4: Weighing and standardization of herbal powders prior to incorporation into the soap matrix.

4. Soap making methodologies: Cold process, Hot Process and Melt and Pour Process

The selection of an appropriate soap-making methodology plays a decisive role in determining the stability, efficacy, and overall quality of polyherbal soap formulations (Ghosh et al., 2016). Different manufacturing approaches vary in their thermal exposure, processing time, and suitability for incorporating heat-sensitive herbal constituents. Consequently, the cold process, hot process, and melt-and-pour methods are commonly employed in herbal soap production, each offering distinct advantages depending on formulation objectives and scale of production.

The cold process method involves combining oils and an aqueous sodium hydroxide solution at relatively low temperatures, allowing saponification to occur gradually over an extended curing period. Herbal additives are incorporated at the “trace” stage, when the soap mixture begins to thicken, ensuring uniform dispersion while minimizing degradation of bioactive compounds. This method requires a curing period of approximately 4–6 weeks, during which excess moisture evaporates and the soap attains optimal hardness and mildness. In contrast, the hot process method follows a similar initial mixing of oils and lye but includes a controlled heating or “cooking” phase that accelerates saponification. This approach reduces curing time and allows for faster product turnover; however, prolonged heat exposure may partially compromise thermolabile phytochemicals if not carefully managed. The melt-and-pour method utilizes a pre-saponified soap base, either transparent or opaque, which is melted and blended with herbal additives before being poured into molds. While this method offers simplicity, consistency, and ease of production, it provides comparatively less control over the chemical composition of the soap base (Table 2).

For the cold process method, a representative formulation includes a balanced blend of base oils selected to optimize cleansing performance, hardness, and skin conditioning. The oil phase typically consists of 40% olive oil, 20% coconut oil, 20% palm oil or a sustainable alternative, and 10% neem oil, with each oil contributing specific functional attributes such as mildness, lather formation, and antimicrobial support. The lye solution is prepared using sodium hydroxide (NaOH), with the required quantity calculated precisely based on the cumulative saponification values of the selected oils to ensure complete reaction without residual alkalinity.

Table 2. Comparison of soap-making methodologies for polyherbal formulations

Method	Key features	Advantages	Limitations
Cold process	Low-temperature saponification, long curing	Preserves bioactives, formulation control	Longer curing time
Hot process	Heat-assisted saponification	Faster production	Possible phytochemical degradation
Melt and pour	Pre-saponified base	Simple, consistent	Limited formulation flexibility

Herbal additives are incorporated in controlled amounts to achieve antimicrobial efficacy while maintaining acceptable sensory properties. Finely powdered neem leaf is added at approximately 15–20 g, providing a concentrated source of antimicrobial phytochemicals. Turmeric powder is included at low levels, typically 1–2 teaspoons, to deliver antimicrobial and antioxidant benefits while minimizing excessive coloration. Finely powdered tulsi leaf is incorporated at approximately 1 tablespoon, contributing antimicrobial and skin-soothing properties. During processing, the lye solution is prepared under strict safety conditions and allowed to cool before being combined with the melted oils. The mixture is blended until a light trace is achieved, at which point the herbal powders and tulsi essential oil are added and uniformly dispersed to ensure homogeneous distribution of bioactive constituents (Figure 5).

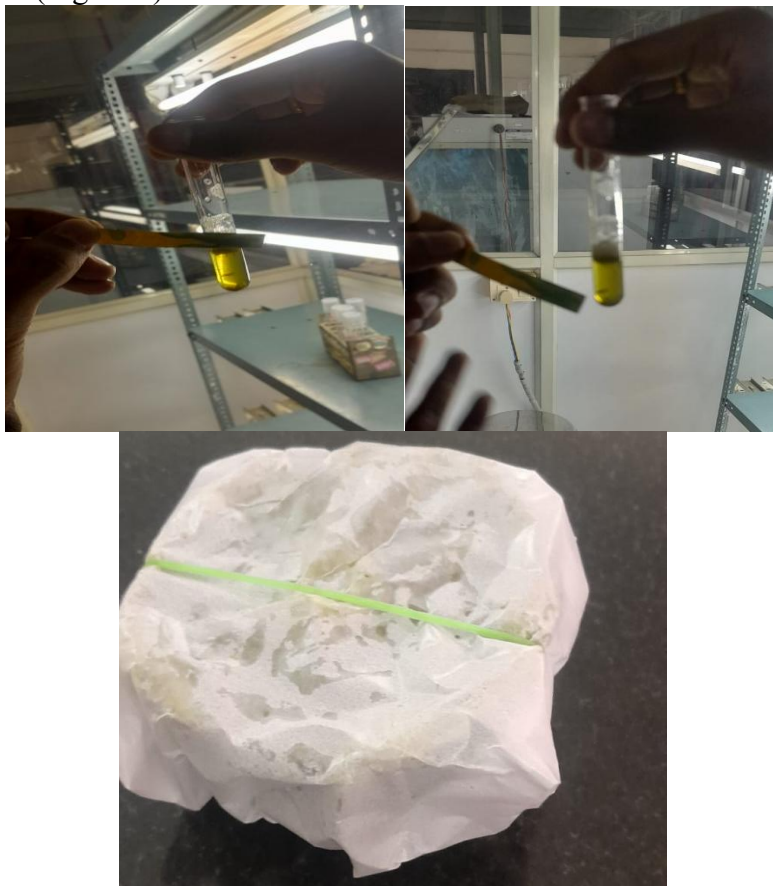


Figure 5: Key stages of soap-making methodologies employed in polyherbal soap formulation.

The resulting soap batter is subsequently poured into molds and insulated to facilitate controlled saponification. After unmolding within 24–48 hours, the soap bars are cured under ambient, controlled conditions for 4–6 weeks to allow moisture reduction, completion of saponification, and attainment of optimal hardness, stability, and performance (Figure 6).



Figure 6: Final cured polyherbal soap bars obtained after completion of the curing process.

5. Review of efficacy: scientific validation

The antimicrobial efficacy of herbal soaps formulated with neem, turmeric, and tulsi has been supported by a substantial body of experimental research, providing scientific validation for their use in dermatological cleansing applications. Multiple formulation-based and in vitro studies have demonstrated that soaps incorporating these botanicals exhibit measurable antimicrobial activity against common skin pathogens (Lakhanapuram et al., 2025). These findings indicate that the incorporation of plant-derived bioactive compounds into soap matrices can retain functional efficacy despite the alkaline environment and rinse-off nature of the formulation.

In addition to literature-based validation, the formulated polyherbal soap was subjected to physicochemical and performance evaluation to assess product quality and functional suitability. The results of laboratory testing are summarized in Table 3.

Table 3. Physicochemical and performance evaluation of the polyherbal soap

Parameter	Observed value
Total Fatty Matter (TFM)	19.83 g/100 g
pH	9.45
Foam height	15 cm
Free alkali content	0 g/100 g
Saponification value	9.25 g/100 g
Performance test	Good

The observed values indicate acceptable soap quality, with adequate fatty matter content, absence of free alkali, and favorable foaming and cleansing characteristics. The pH value falls within the commonly accepted range for bathing soaps, supporting skin compatibility during routine use. These results provide objective evidence that the formulation meets standard quality parameters while retaining functional performance.

Investigations evaluating neem- and turmeric-containing soaps have reported significant inhibitory effects against bacterial strains such as *Staphylococcus aureus* and *Escherichia coli*, with antimicrobial performance comparable to that of certain commercially available medicated soaps. Such observations highlight the capacity of neem and turmeric to deliver effective antimicrobial

action when formulated into topical cleansing products, supporting their relevance in routine hygiene and infection control.

Additional experimental evidence has demonstrated that tulsi extracts possess strong antibacterial activity against microorganisms commonly associated with skin infections, particularly in warm and humid environments where microbial proliferation is more pronounced. These findings reinforce the suitability of tulsi as a functional ingredient in herbal soap formulations intended for regular use in diverse climatic conditions.

The combined incorporation of neem, turmeric, and tulsi offers a distinct synergistic advantage, as each plant contributes complementary biological functions. Neem provides broad-spectrum antimicrobial activity, turmeric enhances antibacterial efficacy while simultaneously exerting anti-inflammatory and antioxidant effects, and tulsi contributes additional antimicrobial potency along with skin-calming and sensory benefits. This functional synergy enhances overall product efficacy, supports skin barrier maintenance, and strengthens the scientific rationale for the development of polyherbal soaps as natural alternatives to synthetic antimicrobial cleansing agents.

6. Challenges and considerations

The formulation of polyherbal soaps, while scientifically promising, presents several technical, stability-related, and dermatological challenges that must be carefully addressed to ensure product efficacy, safety, and reproducibility. One of the primary challenges lies in the standardization of plant-derived raw materials, as the concentration of bioactive compounds in neem, turmeric, and tulsi can vary considerably depending on geographical origin, cultivation conditions, harvesting time, and post-harvest processing. This inherent variability complicates batch-to-batch consistency in antimicrobial performance and overall product quality. To mitigate this issue, controlled sourcing, standardized processing protocols, and the use of characterized herbal extracts are essential components of quality assurance in herbal soap manufacturing. Stability constitutes another critical consideration in the development of herbal soap formulations. Natural oils and phytochemicals are susceptible to oxidative degradation, which can result in rancidity, loss of antimicrobial potency, and reduced shelf life. Oils rich in unsaturated fatty acids are particularly prone to oxidation, especially when exposed to heat, light, and oxygen during storage. The strategic incorporation of natural antioxidants, such as rosemary extract (ROE), along with appropriate packaging and controlled storage conditions, is therefore crucial to preserving the physicochemical integrity and functional performance of the final product. Sensory and aesthetic attributes also influence consumer acceptance and product success. Turmeric, despite its well-established antimicrobial and anti-inflammatory properties, possesses strong natural pigmentation that may lead to temporary skin staining when used at higher concentrations. This limitation can be effectively managed by maintaining turmeric at low inclusion levels, ensuring complete saponification, and allowing adequate curing time, thereby minimizing pigment transfer during routine use without compromising efficacy. Dermatological safety remains a fundamental consideration in herbal soap formulation. Although neem, turmeric, and tulsi are generally regarded as safe for topical application, individual variability in skin sensitivity may result in irritation or allergic reactions in susceptible users. Consequently, precautionary measures such as patch testing, transparent labeling, and adherence to recommended usage guidelines are essential to support consumer safety and responsible product development (EMA, 2018).

7. Conclusions and future perspectives

The development of an antimicrobial soap formulated with neem, turmeric, and tulsi represents a scientifically robust and practically viable strategy for modern skin hygiene that integrates traditional medicinal knowledge with contemporary formulation science. Evidence reviewed in this study confirms that these botanicals possess complementary antimicrobial, anti-inflammatory, and skin-protective properties that remain functionally effective within soap formulations. Their combined use provides a broad-spectrum, natural defense against common skin pathogens while avoiding the environmental persistence and health concerns associated with synthetic antimicrobial agents. From

a manufacturing standpoint, the cold process method offers an optimal balance between formulation control and preservation of bioactive phytochemicals, making it particularly suitable for polyherbal soap production. Gradual saponification under controlled conditions minimizes thermal degradation and supports product stability. In contrast, the melt-and-pour method provides a simplified and accessible alternative for small-scale production and rapid formulation development, although it allows less flexibility in modifying base composition. Selection of the manufacturing approach should therefore be guided by production scale, functional requirements, and intended application. A key strength of the formulation lies in the synergistic interaction among neem, turmeric, and tulsi. Neem contributes robust antimicrobial activity, turmeric provides anti-inflammatory and antioxidant support, and tulsi enhances antimicrobial efficacy while promoting skin comfort and sensory acceptability. This functional complementarity strengthens the relevance of the polyherbal approach for routine personal hygiene without the risks associated with prolonged exposure to synthetic antimicrobials. Future research should prioritize standardization of herbal extracts to ensure consistent phytochemical profiles and reproducible antimicrobial performance. In addition, well-designed in vivo and user-based studies are required to validate safety, tolerability, and consumer-perceived benefits. Further optimization of formulation strategies aimed at improving phytochemical stability within the soap matrix may enhance long-term efficacy. Within the broader context of sustainability and preventive skin care, the neem–turmeric–tulsi formulation offers a responsible and forward-looking pathway for next-generation herbal hygiene products.

References

1. Alzohairy, M. A. (2016). Therapeutic role of *Azadirachta indica* (Neem) and their active constituents in diseases prevention and treatment. *Evidence-Based Complementary and Alternative Medicine*, 2016, 7382506. <https://doi.org/10.1155/2016/7382506>
2. Carey, D. E., & McNamara, P. J. (2015). The impact of triclosan on the spread of antibiotic resistance in the environment. *Frontiers in Microbiology*, 5, 780. <https://doi.org/10.3389/fmicb.2014.00780>
3. Dréno, B., Araviiskaia, E., Berardesca, E., Bieber, T., Hawk, J., Sanchez Viera, M., & Wolf, R. (2019). Microbiome in healthy skin: Update for dermatologists. *Journal of the European Academy of Dermatology and Venereology*, 33(12), 2274–2285.
4. European Medicines Agency. (2018). *Guideline on quality of herbal medicinal products/traditional herbal medicinal products*. EMA.
5. Ghosh, P., Gaba, B., & Das, S. (2016). Preparation and evaluation of herbal soap using plant extracts. *International Journal of Pharmaceutical Sciences Review and Research*, 40(1), 243–247.
6. Halden, R. U. (2014). On the need and speed of regulating triclosan and triclocarban in the United States. *Environmental Science & Technology*, 48(7), 3603–3611.
7. Hewlings, S. J., & Kalman, D. S. (2017). Curcumin: A review of its effects on human health. *Foods*, 6(10), 92. <https://doi.org/10.3390/foods6100092>
8. Hoang, H. T., Moon, J.-Y., & Lee, Y.-C. (2021). *Natural antioxidants from plant extracts in skincare cosmetics: Recent applications, challenges and perspectives*. *Cosmetics*, 8(4), 106.
9. Islas, J. F., Acosta, E., Zuca, G., Delgado-Gallegos, J. L., Moreno-Treviño, M. G., Escalante, B., & Moreno-Cuevas, J. E. (2020). An overview of Neem (*Azadirachta indica*) and its potential impact on health. *Journal of Functional Foods*, 74, 104171.
10. Jamshidi, N., & Cohen, M. M. (2017). The clinical efficacy and safety of Tulsi in humans: A systematic review of the literature. *Evidence-Based Complementary and Alternative Medicine*, 2017, Article 9217567. <https://doi.org/10.1155/2017/9217567>
11. Lakhanapuram, H. K., Bunluepuech, K., Somsiripan, T., Khongkhai, H., Sangkanu, S., Saengsawang, P., & Mitsuwan, W. (2025). Assessment of antibacterial, antibiofilm, and physicochemical characteristics of *Curcuma longa* L. extract and soap containing *C. longa* extract against *Staphylococcus aureus*. *Journal of the Saudi Society of Agricultural Sciences*, 24(8), 65.

12. Manalo, R. J., Dosmanos, E. B., Estrada, C. A., Almendra, S. D., & Estorico, G. C. (2024). *A systematic review on the sensitivity of bacteria to different plant extracts used in soap formulation*. International Journal of Innovative Science and Research Technology, 9(11), 1490–1501.
13. Marchese, A., Arciola, C. R., Barbieri, R., Silva, A. S., Nabavi, S. F., Tsetegho Sokeng, A. J., & Nabavi, S. M. (2016). Antibacterial and antifungal activities of thymol: A brief review of the literature. *Food Chemistry*, 210, 402–414. <https://doi.org/10.1016/j.foodchem.2016.04.111>
14. Panda, S. K., Mohanta, Y. K., Padhi, L., Park, Y. H., Mohanta, T. K., & Bae, H. (2022). Large-scale screening of ethnomedicinal plants for identification of potential antibacterial compounds. *Molecules*, 27(3), 1095.
15. Pattanayak, P., Behera, P., Das, D., & Panda, S. K. (2017). *Ocimum sanctum* Linn. (Tulsi): A reservoir plant for therapeutic applications. *Pharmacognosy Reviews*, 11(21), 18–26.
16. Subapriya, R., & Nagini, S. (2015). Medicinal properties of neem leaves: A review. *Current Medicinal Chemistry*, 22(8), 975–989.
17. Teow, S. Y., Liew, K., Ali, S. A., Khoo, A. S. B., & Peh, S. C. (2016). Antibacterial action of curcumin against *Staphylococcus aureus*: A brief review. *Journal of Tropical Medicine*, 2016, 2853045. <https://doi.org/10.1155/2016/2853045>
18. Tyagi, P., Singh, M., Kumari, H., Kumari, A., & Mukhopadhyay, K. (2015). Bactericidal activity of curcumin against *Staphylococcus aureus* and *Escherichia coli* is mediated by disrupting the membrane integrity. *Frontiers in Microbiology*, 6, 147.
19. Wylie, M. R., & Merrell, D. S. (2022). *The antimicrobial potential of the neem tree Azadirachta indica*. *Frontiers in Pharmacology*, 13, Article 891535. <https://doi.org/10.3389/fphar.2022.891535>