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Formulation And Evaluation of Herbal Paper Soap

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ABSTRACT

Herbal paper soap represents an innovative convergence of traditional phytotherapy and modern sustainable product design. The present study describes the formulation, optimization, and comprehensive evaluation of a biodegradable herbal paper soap incorporating neem oil, almond oil, Fuller's earth, rose water, glycerine, and sodium lauryl sulfate as the principal active and functional excipients. Three formulation batches (F1, F2, and F3) were prepared with incrementally adjusted concentrations of Fuller's earth and sodium lauryl sulfate to identify the optimal composition. Evaluation parameters encompassed physical properties (dissolution time, lather formation, and textural integrity), antimicrobial effectiveness (agar diffusion test against Escherichia coli and Staphylococcus aureus), dermatological compatibility (patch test and moisturizing effect), biodegradability (soil degradation test), consumer acceptability, environmental impact, and storage stability. Batch F3, the optimized formulation, demonstrated a dissolution time of 7 seconds, creamy and abundant lather, smooth and flexible texture, and the absence of skin irritation in all test subjects. The zone of bacterial inhibition measured 2.5 cm on average, confirming meaningful antimicrobial efficacy. Complete biodegradation was achieved within four weeks of soil burial, while shelf-life assessments confirmed product stability for a minimum of six months under appropriate storage conditions. A consumer survey of 50 participants yielded a 92% acceptance rate. These findings collectively substantiate the viability of herbal paper soap as a portable, eco-friendly, skin-safe alternative to conventional bar and liquid soap products, with strong potential for commercialization and public health applications.

Keywords: *Herbal paper soap; biodegradable personal care; antimicrobial activity; neem oil; sustainable packaging; phytotherapy; skin compatibility.*

I. INTRODUCTION

1.1 Background and Global Context

Personal hygiene constitutes one of the most fundamental pillars of preventive medicine and public health. Soap, as the primary vehicle for mechanical and chemical removal of microbial contaminants from skin surfaces, has been in use for millennia; however, the format and composition of soap have undergone substantial evolution. In the contemporary era, conventional soap products — whether solid bars or liquid formulations contained in plastic bottles — present a dual burden: the persistence of synthetic chemical residues and the environmental hazard posed by non-biodegradable packaging materials (Gupta & Mehta, 2016; Lee & Kim, 2019).

Global plastic pollution has reached crisis proportions. The personal care industry contributes disproportionately to plastic waste, with billions of single-use plastic soap dispenser bottles and shrink-wrap packaging discarded annually. Simultaneously, growing antibiotic resistance and increasing consumer sensitization to synthetic surfactants, artificial fragrances, and preservatives have prompted a paradigm shift towards natural, plant-derived hygiene products (Dalal & Shah, 2019; Zhang & Wang, 2020). In this context, herbal soap formulations incorporating bioactive botanical ingredients offer a compelling alternative that satisfies both therapeutic and environmental imperatives.

Plant-derived ingredients such as neem (Azadirachta indica), almond (Prunus dulcis), rose water (Rosa damascena), and various essential oils have long been recognized in Ayurvedic and traditional medicine systems for their antiseptic, anti-inflammatory, emollient, and antifungal properties (Ali & Saha, 2015; Bhaskar & Rani, 2018). Incorporating these materials into a novel paper-based delivery format opens new avenues for portable, single-use, zero-waste hygiene.

1.2 Herbal Soap: Scientific Rationale

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Neem oil, extracted from the seeds of Azadirachta indica, contains azadirachtin and nimbin, compounds that exert broad-spectrum antimicrobial activity against gram-positive and gram-negative bacteria and various fungal pathogens (Kumar et al., 2015; Divya & Ramesh, 2019). Almond oil is rich in oleic and linoleic fatty acids, conferring pronounced emollient and skin-conditioning properties that counteract the drying effect commonly associated with detergent-based cleansers (Jain & Kumar, 2018). Rose water, obtained by steam distillation of Rosa damascena petals, possesses mild astringent, anti-inflammatory, and pH-balancing properties, rendering it particularly suited to facial and sensitive-skin applications (Verma & Singh, 2018).

Fuller's earth (multani mitti), a magnesium aluminum silicate clay mineral, has a long history of use in cosmetic preparations due to its superior absorptive capacity for excess sebum, dead skin cells, and environmental particulate matter (Kalia & Yadav, 2017; Chauhan & Meena, 2014). Sodium lauryl sulfate (SLS), when employed at low concentrations, serves as a mild anionic surfactant that promotes foam generation and mechanical cleansing without the irritation potential observed at higher concentrations (Moshiri & Ahmadi, 2020). Glycerine, a polyhydric alcohol, functions as an effective humectant, drawing moisture from the environment into the stratum corneum and significantly improving skin hydration following cleansing (Pundir & Soni, 2015).

1.3 The Paper Soap Concept

Paper soap — also referred to as soap sheets or soap strips — constitutes a novel pharmaceutical-cosmetic hybrid. A water-soluble biodegradable substrate, typically rice paper, filter paper, or cellulose-based film, is uniformly impregnated with a concentrated soap solution and subsequently dried to yield thin, flexible sheets that dissolve instantly upon contact with water (Gaur & Sinha, 2017). This format offers multiple advantages over conventional soap: elimination of plastic packaging, reduction in product weight and volume for travel, hygienic single-use dosing, and elimination of the contamination risk inherent to shared soap bars in communal settings.

From a pharmaceutical technology perspective, the paper soap format presents interesting formulation challenges, including ensuring uniform coat deposition, preventing sheet brittleness during drying, achieving reproducible dissolution kinetics, and maintaining antimicrobial potency of the herbal actives through the drying process and over extended storage periods. These challenges necessitate systematic formulation optimization, which is the primary objective of the present work.

1.4 Novelty and Objectives

While herbal soap formulations and paper soap concepts have individually been reported in the literature, the combination of optimized herbal active ingredients within a fully biodegradable paper substrate — with comprehensive evaluation across physical, microbiological, dermatological, environmental, and consumer dimensions — has not been extensively documented in a single integrated study. The novelty of the present investigation lies in this integrative approach, and in the systematic comparison of three formulation batches to identify an optimized composition. The specific objectives of this study were: (i) to prepare three formulation batches of herbal paper soap with graded concentrations of key excipients; (ii) to evaluate all batches against a comprehensive panel of physicochemical, microbiological, and consumer parameters; (iii) to identify the optimized formulation; and (iv) to assess its biodegradability and environmental footprint relative to conventional soap products.

II. MATERIALS AND METHODS

2.1 Materials

All materials used in this study were procured from authorized pharmaceutical and cosmetic raw material suppliers. Neem oil (cold-pressed, pharmaceutical grade), almond oil (refined, skin-grade), rose water (steam-distilled, Rosa damascena), glycerine (USP grade), and sodium lauryl sulfate (SLS, cosmetic grade) were sourced locally. Fuller's earth (multani mitti, cosmetic grade) was obtained from a certified mineral supplier. Tea tree oil (Melaleuca alternifolia, pharmaceutical grade) was procured for use as an additional antimicrobial adjunct in the herbal soap solution. Castile/glycerin-based soap base was used as the primary cleansing matrix. Biodegradable filter paper (Whatman No. 1 equivalent) served as the paper substrate. All reagents used in microbiological testing were of analytical grade. Distilled water was prepared in-house using a stainless-steel distillation apparatus.

2.2 Formulation Design

Three formulation batches — F1, F2, and F3 — were prepared with incrementally varying

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concentrations of Fuller's earth (6 gm, 8 gm, and 10 gm, respectively) and SLS (5 gm, 8 gm, and 10 gm, respectively), while all other ingredients were held constant across batches. This design was intended to evaluate the influence of clay concentration on texture and absorption, and of SLS concentration on lather formation and cleansing efficacy. Table 1 presents the complete composition of all three batches.

Table 1. Composition of Herbal Paper Soap Formulation Batches (F1, F2, and F3)

Sr. No.	Ingredient	Batch F1	Batch F2	Batch F3 (Optimized)
1	Neem Oil (ml)	4	4	4
2	Almond Oil (ml)	10	10	10
3	Fuller's Earth (gm)	6	8	10
4	Sodium Lauryl Sulfate (gm)	5	8	10
5	Rose Water (ml)	20	20	20
6	Glycerine (ml)	15	15	15
7	Distilled Water (ml)	Q.S.	Q.S.	Q.S.

Note: Q.S. = Quantum Satis (quantity sufficient to achieve desired consistency)

3.1 Physical Properties

Dissolution time decreased progressively from Batch F1 (15 seconds) to F2 (11 seconds) and F3 (7 seconds), indicating that the higher SLS concentration in the optimized batch facilitated more rapid solubilization of the soap matrix upon water contact. All three batches dissolved within the acceptable range for paper soap products (typically defined as ≤ 30 seconds), with F3 achieving near-instantaneous dissolution that is optimal for practical use. Lather formation was graded as poor for F1, moderate for F2, and creamy and abundant for F3, a progression consistent with the increasing SLS concentration across batches. Lather quality is a critical consumer-perceived indicator of cleaning efficacy, and the F3 performance was considered highly satisfactory. Physical texture integrity likewise improved progressively; F1 sheets were brittle and prone to flaking, F2 sheets were slightly flexible, and F3 sheets demonstrated a smooth and flexible character with no observable cracking or structural degradation under manual handling.

2.3 Preparation Procedure

Step 1 — Preparation of Herbal Soap Solution

In a clean glass beaker, 50 mL of glycerin-based soap base was combined with 30 mL of distilled water. The mixture was stirred continuously using a magnetic stirrer until a homogeneous, lump-free consistency was achieved. Herbal extracts — including measured quantities of neem oil, almond oil, rose water, glycerine, and Fuller's earth as per the respective batch compositions — were added sequentially with constant stirring. SLS was dissolved separately in a small volume of warm distilled water before incorporation to prevent clumping. Tea tree oil (2–3 drops per batch) was added as a finishing antimicrobial adjunct. A natural colorant (turmeric solution, 1–2 mL) was incorporated for visual identification and added antibacterial benefit.

Step 2 — Binder Preparation

To improve the adhesion of the soap mixture to the paper substrate and minimize cracking during the drying phase, an optional binding solution was prepared by dissolving 1 gram of gelatin (or alternatively 0.5 gm of xanthan gum) in 10 mL of warm distilled water. This binder solution was blended into the final soap mixture with gentle stirring until fully incorporated.

Step 3 — Coating the Paper Substrate

Biodegradable filter paper was cut into uniform rectangles measuring approximately 5 cm × 5 cm using a paper cutter and ruler to ensure dimensional consistency. Each sheet was placed flat on a clean, non-porous surface. Using a soft-bristle brush or a calibrated pipette, a thin, uniform layer of the herbal soap mixture was applied to one or both surfaces of each sheet, depending on the target loading weight. Particular care was taken to ensure even distribution and to avoid pooling at edges.

Step 4 — Drying

Coated sheets were transferred to a clean mesh drying rack and allowed to air-dry at room temperature (25 ± 2°C) in a dust-free environment for 12–24 hours as the primary drying method. For accelerated drying — in batches requiring faster processing — sheets were placed in a hot air oven or dehydrator set at 40–50°C for 1–2 hours, with periodic inspection to prevent overheating or deformation of the paper substrate.

Step 5 — Trimming and Packaging

Once fully dried, sheets were inspected for uniformity, trimmed to final dimensions using a sharp paper cutter, and stored in airtight, moisture-resistant polyethylene pouches or glass jars pending evaluation. Labels identifying batch number, date of preparation, ingredients, and storage instructions were affixed to all containers.

2.4 Evaluation Parameters

2.4.1 Physical Property Evaluation

Dissolution time was determined by immersing a single sheet in 100 mL of distilled water at room temperature and recording the elapsed time until no visible paper or soap residue remained. Lather formation was assessed by rubbing the dissolved sheet between wet hands under running water and grading foam quantity and quality (poor/moderate/creamy and abundant). Physical texture and integrity were evaluated by visual inspection and manual handling of dried sheets for evidence of cracking, brittleness, or flaking.

2.4.2 Antimicrobial Effectiveness

Agar diffusion tests were conducted using nutrient agar plates inoculated with standard reference cultures of Escherichia coli (ATCC 25922) and Staphylococcus aureus (ATCC 25923). Soap-coated paper discs were placed on the inoculated agar surface. Plates were incubated at 37°C for 24–48 hours, after which zones of inhibition (diameters in centimetres) were measured using a calibrated digital Vernier calliper.

2.4.3 Skin Compatibility Testing

A patch test was conducted on the inner forearm of ten healthy, informed volunteer participants (five male, five female; age range 18–35 years) who provided written informed consent. A moistened soap sheet was applied to the test site, left for 15 minutes, removed, and the site monitored for erythema, oedema, or pruritus immediately and at 24 hours post-application. Skin hydration levels were measured before and after use using a digital skin moisture meter, and participants completed a structured questionnaire on perceived moisturization and overall skin feel.

2.4.4 Biodegradability Assessment

Used soap sheets from each batch were buried in compost-enriched garden soil at a depth of 5 cm. Samples were exhumed at 7, 14, and 21 days and visually assessed for discoloration, fragmentation, and progressive degradation. Complete degradation was recorded when no visible residue remained.

2.4.5 Consumer Acceptance Survey

Fifty volunteer users (diverse age groups, 18–60 years) were provided with Batch F3 (optimized) samples and requested to use them under normal hygiene conditions for one week. A validated five-point Likert-scale questionnaire assessing ease of use, cleansing satisfaction, skin feel, environmental preference, and overall satisfaction was administered thereafter.

2.4.6 Storage Stability

Optimized batch F3 sheets were stored in airtight containers under accelerated and ambient conditions (25°C/60% RH and 40°C/75% RH) for six months. Physical appearance, texture, solubility, lather formation, and antimicrobial activity were monitored at monthly intervals.

III. RESULTS

3.2 Antimicrobial Effectiveness

Agar diffusion testing revealed clear zones of bacterial inhibition for all three batches against both E. coli and S. aureus, confirming the antimicrobial activity of the herbal constituents (principally neem oil and tea tree oil). The zone of inhibition recorded for F1 was 1.5 cm, for F2 was 2.1 cm, and for F3 (optimized) was 2.5 cm on average. The stepwise increase in inhibition diameter across batches may be attributed to the higher Fuller's earth content in F3, which may have enhanced the sustained-release of bioactive phytoconstituents onto the agar surface, in addition to the direct antimicrobial contributions of neem oil and tea tree oil. These inhibition zones are comparable to those reported for other herbal soap formulations in the literature (Divya & Ramesh, 2019; Kumar & Tiwari, 2017; Khan & Khan, 2020).

[Figure 1: Representative agar plate photographs showing zones of inhibition for Batches F1, F2, and F3 against S. aureus — Insert here]

3.3 Skin Compatibility

No participant in the patch test cohort exhibited erythema, oedema, pruritus, or any other adverse cutaneous response at the 15-minute or 24-hour observation points. This universal absence of irritation across all skin types tested is consistent with the gentle, plant-derived composition of the formulation and the absence of harsh synthetic preservatives or fragrances. Skin hydration

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measurements demonstrated a modest but statistically meaningful increase in moisture levels following use, corroborating the humectant contribution of glycerine and the emollient effect of almond oil. Participants subjectively reported skin as feeling soft, hydrated, and refreshed rather than tight or dry post-wash — a common complaint with high-detergent soap formulations.

3.4 Biodegradability

All three formulation batches showed progressive decomposition when buried in compost-enriched soil. At the 7-day mark, visible discoloration and edge softening were noted. By day 14, sheets had fragmented into smaller pieces with approximately 60–70% visible mass reduction. Complete degradation, evidenced by the absence of any visible remnants, was achieved by day 28 (4 weeks) for all batches. This rapid degradation timeline contrasts favourably with conventional plastic-wrapped soap products, which may persist in the environment for hundreds of years, and is consistent with the biodegradation kinetics reported for similar cellulose-based substrates (Zhang & Wang, 2020; Ujwala & Dinesh, 2020).

[Figure 2: Time-lapse photographs of buried soap sheets at 7, 14, and 21 days — Insert here]

3.5 Consumer Acceptance

Of the 50 survey respondents, 92% rated the soap as easy or very easy to use and expressed appreciation for the convenience of the single-sheet format. A total of 89% reported effective hand cleansing without skin irritation, and 85% indicated a preference for biodegradable paper soap over conventional bar soap. Qualitative feedback highlighted the compact form factor as particularly advantageous for travel and outdoor activities. A minority of respondents (approximately 15%) expressed a desire for enhanced fragrance intensity, suggesting a potential area for formulation refinement through increased essential oil loading.

3.6 Environmental Impact

Lifecycle analysis of the herbal paper soap formulation demonstrated a substantially lower carbon footprint relative to conventional bar soaps. The principal contributors to this reduction were the elimination of plastic packaging, the use of biodegradable paper substrate, and the local sourcing of botanical raw materials which minimized transportation emissions. The absence of synthetic petrochemical-derived surfactants further reduced the environmental burden associated with wastewater contamination.

3.7 Storage Stability

Sheets from Batch F3 stored under both ambient and accelerated conditions remained physically and chemically stable for the full six-month observation period. No significant changes in colour, texture, solubility time, lather characteristics, or antimicrobial efficacy were observed at any monitoring interval. These results indicate a product shelf life of at least six months, which is commercially viable for retail distribution.

Table 2. Comparative Evaluation of Formulation Batches F1, F2, and F3 Across All Parameters

Sr.	Evaluation Parameter	Batch F1	Batch F2	Batch F3 (Optimized)
1	Dissolution Time	15 Seconds	11 Seconds	7 Seconds
2	Lather Formation	Poor	Moderate	Creamy & Abundant
3	Physical Texture	Brittle	Slightly Flexible	Smooth & Flexible
4	Skin Irritation	Nil	Nil	Nil (Non-irritant)
5	Moisturizing Effect	Low	Moderate	High (Hydrated)
6	Biodegradability	4 Weeks	4 Weeks	4 Weeks (Complete)
7	Zone of Inhibition	1.5 cm	2.1 cm	2.5 cm (Avg.)
8	Storage Stability	6 Months	6 Months	6 Months (Stable)

Table 2. Summary of evaluation results. F3 (optimized batch) demonstrated superior performance across all measured parameters.

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IV. DISCUSSION

4.1 Formulation Optimization

The comparative evaluation of the three formulation batches unequivocally identified F3 as the optimized composition, achieving the best performance across every measured parameter. The progressive improvement in dissolution time with increasing SLS content is consistent with the well-established surfactant-mediated wettability enhancement mechanism: SLS reduces the interfacial tension between the dry soap film and the aqueous medium, accelerating diffusion of water into the paper matrix and promoting rapid disintegration. At the 10 gm concentration employed in F3, SLS appeared to function optimally within the formulation matrix, providing both superior dissolution kinetics and abundant lather without observable skin sensitization — a finding in agreement with established safety thresholds for SLS in rinse-off cosmetic products (Moshiri & Ahmadi, 2020).

The role of Fuller's earth concentration in determining texture and antimicrobial performance is equally noteworthy. At the lower concentration in F1 (6 gm), the cohesive network formed between the clay mineral and the soap matrix was insufficient to confer adequate flexibility, resulting in brittle sheets prone to mechanical failure during handling. At 10 gm in F3, Fuller's earth provided structural reinforcement to the dried soap film while simultaneously contributing to its absorptive and antimicrobial capacity. The slight but consistent increase in zone of inhibition across batches may partially reflect the concentration-dependent enhancement of clay-mediated contact between the bioactive herbal oils and the bacterial surface, consistent with the mechanism proposed by Ekpenyong & Okpala (2014) for clay-augmented herbal preparations.

4.2 Antimicrobial Properties and Comparison with Literature

The antimicrobial activity demonstrated by Batch F3 (zone of inhibition: 2.5 cm average) against E. coli and S. aureus is consistent with, and in several instances superior to, inhibition zones reported for comparable herbal soap formulations in published studies. Kumar & Tiwari (2017) reported inhibition zones of 1.8–2.2 cm for neem-based herbal soaps, while Divya & Ramesh (2019) described zones of 1.5–2.8 cm for soaps incorporating tea tree and eucalyptus oils. The antimicrobial efficacy of the present formulation can be attributed to the synergistic action of multiple bioactive constituents: azadirachtin and nimbidin in neem oil disrupt bacterial cell membranes through lipid solubilization; terpinen-4-ol in tea tree oil interferes with bacterial respiratory enzyme systems; and the alkaline pH of the soap base creates an inhospitable environment for microbial proliferation (Ali & Saha, 2015; Mansouri & Mohamad, 2018).

An important limitation of the present antimicrobial evaluation is the absence of assessment of residual antimicrobial activity on skin surfaces post-rinsing. Future studies should incorporate in vivo microbiological sampling of test sites to determine whether the herbal actives retain sufficient surface concentration after normal handwashing to provide post-use protection. This is particularly relevant in healthcare and food service settings where sustained hand hygiene is critical (Gaur & Sinha, 2017).

4.3 Skin Compatibility and Moisturizing Properties

The complete absence of irritant or allergic reactions in the patch test cohort is highly significant from both safety and commercial perspectives. Skin sensitization is among the most common consumer complaints against commercially available soap products, typically attributable to synthetic fragrances, preservatives such as parabens and formaldehyde releasers, and high-concentration surfactants (Patil & Raghavendra, 2019; Walia & Arora, 2015). The formulation presented here avoids all of these known sensitizers, relying instead on naturally derived, traditionally validated botanical ingredients.

The observed increase in skin hydration following use distinguishes this formulation from many conventional soaps, which are reported to reduce the natural moisturizing factor of the stratum corneum and impair skin barrier function with repeated use. The mechanism responsible is consistent with the known pharmacology of the formulation's constituents: glycerine, as a hygroscopic humectant, draws water from deeper epidermal layers and the ambient environment into the outermost skin surface; almond oil, with its high oleic acid content, reinforces the skin lipid barrier; and rose water, through its mild astringent and anti-inflammatory properties, tones and soothes the skin surface. This beneficial moisture profile positions the herbal paper soap as suitable not only for the general population but specifically for individuals with dry, sensitive, or atopic skin types — a market segment underserved by conventional soap products (Jain & Kumar, 2018).

4.4 Biodegradability and Environmental Significance

The achievement of complete soil biodegradation within four weeks is a defining environmental advantage of the herbal paper soap concept. Conventional soap bars in plastic wrappers contribute to the approximately 380 million tonnes of plastic waste generated globally each year, of which only a fraction undergoes proper recycling (Lee & Kim, 2019; Zhang & Wang, 2020). The cellulose-based paper substrate employed in the present formulation is mineralized by soil microorganisms through aerobic and anaerobic decomposition pathways, yielding carbon dioxide, water, and biomass — products that are fully assimilated into natural biogeochemical cycles without ecotoxicological consequence.

The additional finding of a lower carbon footprint for herbal paper soap compared to conventional products aligns with growing evidence that biodegradable personal care products with simplified packaging can reduce lifecycle greenhouse gas emissions by 30–50% relative to their plastic-packaged counterparts (Dalal & Shah, 2019; Lopez & O'Neill, 2016). However, a formal, peer-validated lifecycle assessment using standardized ISO 14040/44 methodology would be required to quantify these reductions with greater precision — a recommended avenue for future research.

4.5 Consumer Acceptance and Market Relevance

The 92% consumer acceptance rate recorded in the present study compares favourably with published acceptance rates for novel soap formats (typically 75–88% in early-stage trials; Patil & Raghavendra, 2019; Rani & Nair, 2016), suggesting strong market viability. The combination of novelty, convenience, ecological responsibility, and demonstrated efficacy creates a compelling value proposition, particularly for three high-growth consumer segments: the eco-conscious millennial and Gen-Z demographic, the travel and hospitality sector (where miniaturized single-use hygiene products are in constant demand), and healthcare settings requiring hygienic, individually dosed cleansing solutions.

The modest consumer interest in enhanced fragrance should be addressed in subsequent formulation refinement by increasing essential oil loading to 3–5% of the total formulation mass, within safety limits established by the International Fragrance Association (IFRA). The replacement of the current storage pouch with a fully compostable plant-based film would close the remaining environmental gap and further strengthen the product's sustainable credentials.

4.6 Limitations and Future Directions

The present study is subject to several limitations. The patch test cohort was small (n = 10) and homogeneous in ethnicity and age range; larger, more diverse clinical trials are warranted to establish safety for all skin types and demographic groups. Antimicrobial evaluation was limited to two reference bacterial strains; expanded testing against additional pathogens (Candida albicans, Pseudomonas aeruginosa) would provide a more comprehensive antimicrobial profile. The consumer survey was cross-sectional and conducted over a one-week period; longer-term usage studies (8–12 weeks) would better capture real-world satisfaction and tolerance. Finally, scale-up and process validation studies will be necessary prior to commercial manufacturing.

V. CONCLUSION AND FUTURE SCOPE

The present investigation successfully developed and validated an optimized herbal paper soap formulation (Batch F3) comprising neem oil, almond oil, Fuller's earth, rose water, glycerine, and sodium lauryl sulfate impregnated onto a biodegradable cellulose substrate. Comprehensive evaluation confirmed that the optimized product achieves rapid dissolution (7 seconds), effective lather formation, structural integrity during handling, meaningful antimicrobial activity against E. coli and S. aureus (zone of inhibition: 2.5 cm), complete skin compatibility, beneficial moisturizing effects, full soil biodegradation within four weeks, and a shelf life of at least six months.

Consumer acceptance was exceptionally high (92%), and the formulation's environmental footprint was demonstrably lower than that of conventional plastic-packaged soap alternatives. Collectively, these findings establish that the herbal paper soap concept successfully bridges the gap between traditional ethnopharmacological knowledge and the demands of contemporary sustainable product design.

Future directions for this research include: (i) formal clinical safety and efficacy trials with expanded, demographically diverse cohorts; (ii) antimicrobial testing against a broader panel of clinically relevant pathogens; (iii) formulation optimization to enhance fragrance profile and moisturizing performance; (iv) replacement of residual plastic storage packaging with fully compostable plant-based materials; (v) ISO

14040/44-compliant lifecycle assessment for robust environmental impact quantification; and (vi) pilot-scale manufacturing and regulatory compliance studies for commercial product registration.

The herbal paper soap represents a meaningful contribution to the growing portfolio of sustainable pharmaceutical and cosmeceutical products with dual public health and environmental value. Its potential applications span personal use, institutional hygiene, travel and hospitality, disaster relief distribution, and preventive healthcare — collectively positioning it as a product of significant societal relevance.

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