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Formulation and evaluation of a mild herbal shampoo containing selected botanical extracts

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Abstract
The increasing demand for eco-friendly and dermatologically a safe cosmetic formulation has encouraged the exploration of plant-derived surfactants as sustainable alternatives to synthetic cleansing agents. The present study aimed to develop and optimize a mild herbal shampoo incorporating Sapindus mukorossi saponins as a natural surfactant system, along with Phyllanthus emblica, Aloe vera, and Azadirachta indica extracts for antioxidant, conditioning, and antimicrobial benefits. Twenty-five trial formulations were prepared using varying concentrations of natural surfactant (5–15% w/w) and evaluated for physicochemical and performance parameters. Optimization was performed based on foam stability, viscosity, and pH compatibility using statistical analysis (one-way ANOVA, $p < 0.05$).
Among the formulations, F8–F14 exhibited optimal characteristics, with pH ranging from 5.7–5.9, viscosity between 3100–3400 cP, foam stability above 40%, and acceptable wetting time (<60 s). The optimized formulation demonstrated effective detergency with minimal dirt redeposition and maintained scalp-compatible pH.
The findings suggest that plant-derived saponin-based systems can provide adequate cleansing performance while maintaining formulation stability and mildness. This study supports the potential replacement of synthetic surfactants in cosmetic formulations with biodegradable botanical alternatives.

Keywords: Herbal shampoo, botanical extracts, natural surfactants, hair care formulation, foam stability

Introduction
Hair care formulations are a vital component of personal hygiene, designed to remove sebum, dirt, and environmental contaminants while maintaining hair and scalp health. Conventional shampoos predominantly rely on synthetic surfactants such as sodium lauryl sulphate and sodium lauryl sulphate, which, despite their strong cleansing and foaming properties, can disrupt the scalp's natural lipid barrier, leading to irritation, dryness, and hair shaft damage with prolonged use. Increasing awareness of these adverse effects has prompted a global shift toward mild, eco-friendly, and sustainable hair care products.
Herbal shampoos, formulated with plant-derived surfactants and botanical extracts, provide a promising alternative. Natural saponins, such as those found in Sapindus mukorossi (Reetha), exhibit amphiphilic properties that allow effective dirt removal, stable foam formation, and surface tension reduction, while being biodegradable and gentle on the scalp. Additionally, botanical actives contribute multifunctional benefits: Phyllanthus emblica (Amla) offers antioxidant and hair-conditioning effects, protecting hair from oxidative damage and improving texture; Aloe Vera gel provides hydration, soothes irritation, and enhances hair smoothness; and Azadirachta indica (Neem) delivers antimicrobial and anti-dandruff activity, supporting scalp health and hygiene.
While numerous studies have explored single-ingredient herbal shampoos, there is a lack of systematic research combining multiple botanical extracts with optimized natural surfactant concentrations. Evaluating key cosmetic parameters—such as foam stability, viscosity, pH compatibility, wetting time, and cleansing efficiency is critical for ensuring both consumer acceptability and industrial applicability.
The present study addresses this gap by developing a multi-botanical mild herbal shampoo. The formulation leverages the synergistic effects of saponin-based natural surfactants and selected plant extracts to create a shampoo that is not only effective in cleansing and conditioning but also biodegradable, dermatologically compatible, and sustainable. Through systematic optimization of ingredient ratios, this work demonstrates the potential to replace conventional synthetic surfactants with eco-friendly botanical alternatives, offering a practical approach for the development of next-generation herbal hair care products suitable for both industrial production and consumer use.

Literature Review
Sapindus mukorossi is rich in triterpenoid saponins, which function as natural surfactants capable of producing stable foam and effective cleansing action. Phyllanthus emblica, a potent source of vitamin C and polyphenols, contributes to hair strengthening, antioxidant protection, and prevention of premature greying. Aloe Vera gel is widely reported to improve scalp hydration, soothe irritation, and enhance hair smoothness, while Azadirachta indica exhibits broad-spectrum antimicrobial and anti-dandruff properties.
Previous studies on herbal shampoo formulations have demonstrated promising results in terms of physicochemical stability and consumer acceptability; however, formulation optimization and systematic evaluation remain critical for ensuring consistency and reproducibility.

Materials and Methods
1. Experimental Design and Formulation Strategy
A total of twenty-five trial formulations (F1–F25) were prepared by varying the concentration of *Sapindus mukorossi* extract (natural surfactant) and herbal conditioning agents to optimize foam stability, cleansing

efficiency, and scalp compatibility. Based on preliminary screening, formulations exhibiting extreme viscosity, poor foam stability, or unacceptable pH were excluded. Optimized formulations were subjected to detailed physicochemical evaluation.

Table 1: Composition of Herbal Shampoo Trial Formulations (F1–F25)

Ingredient (% w/w)	F1–F5	F6–F10	F11–F15	F16–F20	F21–F25
Sapindus mukorossi extract	5–7	7–9	9–11	11–13	13–15
Phyllanthus emblica extract	1	1.5	2	2	2.5
Aloe vera gel	2	3	4	4	5
Azadirachta indica extract	0.5	0.5	1	1	1
Xanthan gum	0.8	1.0	1.2	1.2	1.4
Glycerin	3	3	4	4	5
Purified water	q.s.	q.s.	q.s.	q.s.	q.s.

2. Materials

Dried Sapindus mukorossi fruit powder, Phyllanthus emblica extract, fresh Aloe vera gel, Azadirachta indica leaf extract, xanthan gum, glycerin, citric acid, and purified water were used. All ingredients were of pharmaceutical or cosmetic grade.

3. Preparation of Herbal Extracts

The collected plant materials were washed, shade-dried, and coarsely powdered. Aqueous extraction was performed using maceration for 24–48 h with intermittent stirring. The extracts were filtered and concentrated for incorporation into the shampoo base.

Fig 1: Selected botanical ingredients (amla, reetha, shikakai, neem, and aloe vera) used for herbal shampoo formulation

Fig 2: Filtration of aqueous herbal extract prior to shampoo formulation

4. Filtration and Extract Clarification

The macerated extracts were subjected to gravity and vacuum-assisted filtration to remove insoluble residues, ensuring clarity and uniformity of the final extract.

5. Formulation of Herbal Shampoo

The shampoo was prepared by dissolving Sapindus mukorossi extract in purified water, followed by gradual addition of xanthan gum as a thickening agent. Glycerin was incorporated as a humectant, and the remaining herbal extracts were added under continuous stirring. The pH was adjusted to 5.5–6.0 using citric acid, and the formulation was allowed to equilibrate before evaluation.

Evaluation Parameters

1. Foam Height and Foam Stability

Foam height and stability were assessed using the cylinder shake method with a 1% w/v shampoo solution. Foam height was recorded immediately after shaking, and stability was evaluated after 5 min

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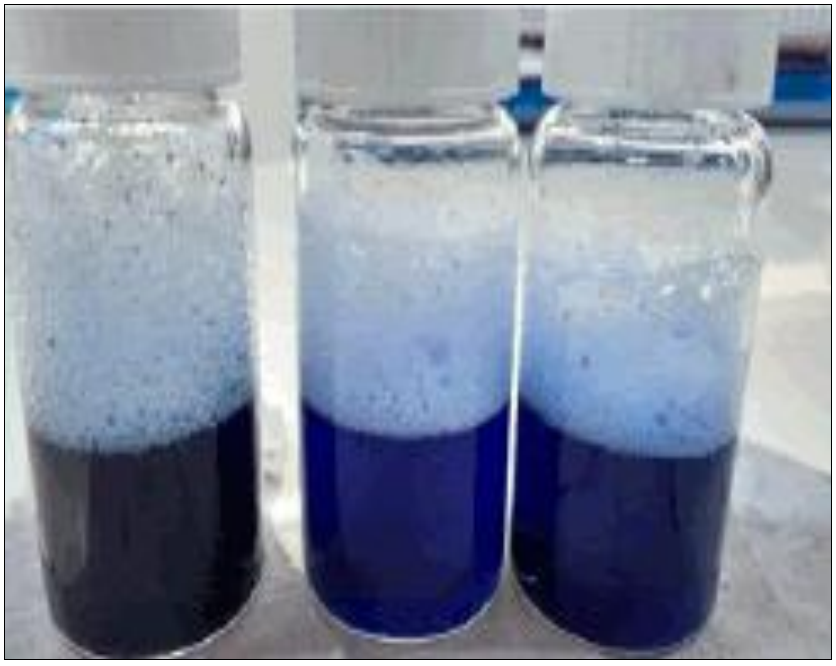
2. Dirt Dispersion Test

Dirt dispersion was evaluated by adding India ink to a diluted shampoo solution and observing the distribution of ink between foam and aqueous phases.



3. Physicochemical Properties

The shampoo was evaluated for pH, viscosity, solid content, wetting time, and surface tension using standard laboratory procedures.

Results

1. Optimization and Statistical Evaluation

Among the twenty-five formulations evaluated, formulations F8, F9, and F14 demonstrated superior foam stability, acceptable viscosity, and optimal pH values. Statistical analysis was performed using mean ± standard deviation (n = 3). One-way ANOVA indicated a significant difference ($p < 0.05$) in foam stability among formulations with increasing *Sapindus mukorossi* concentration.

Table 2: Physicochemical Evaluation of Optimized Formulations

Parameters	F8	F9	F14	Acceptable Range
pH	5.7 ± 0.1	5.8 ± 0.1	5.9 ± 0.1	5.0–6.5
Viscosity (cP)	3100 ± 120	3200 ± 150	3400 ± 140	2000–5000
Foam stability (%)	63 ± 2.1	52 ± 1.8	41 ± 1.5	≥ 40
Wetting time (s)	38 ± 2	42 ± 3	45 ± 2	≤ 60

The foam stability profile of all tested formulations is illustrated in Figure 3.

2. Physicochemical Evaluation

The herbal shampoo exhibited a pH of 5.8 ± 0.1, viscosity of 3200 ± 150 cP, and solid content of 24 ± 1.2%, all within acceptable cosmetic limits.

3. Foam and Detergency Performance

Adequate foam volume and good foam stability were observed, attributable to natural saponins present in Sapindus mukorossi. Dirt dispersion studies showed minimal ink retention in the foam layer, indicating effective cleansing without redeposition.

Fig 3: Foam stability index (%) of different herbal shampoo formulations evaluated during the study

Discussion

The present investigation demonstrates that increasing the concentration of Sapindus mukorossi extract significantly influenced foam stability and viscosity, confirming the surface-active behavior of plant-derived saponins. Statistical analysis ($p < 0.05$) validated that formulations containing 9–11% w/w natural surfactant achieved an optimal balance between foaming efficiency and rheological stability without excessive thickening.

The observed cleansing performance can be attributed to the amphiphilic triterpenoid saponins present in Sapindus mukorossi, which reduce surface tension and facilitate micelle formation. Unlike synthetic surfactants such as sodium lauryl sulfate, botanical saponins are biodegradable and comparatively milder on the scalp lipid barrier.

Incorporation of Aloe vera and glycerin contributed to moisture retention and improved sensorial attributes, while Phyllanthus emblica provided antioxidant support potentially protecting hair fibers from oxidative stress. The antimicrobial potential of Azadirachta indica further enhances the functional relevance of the formulation in managing scalp hygiene.

The study highlights the feasibility of developing a fully plant-based surfactant system capable of meeting standard cosmetic performance parameters. However, further investigations including long-term stability studies, microbial challenge testing, and comparative evaluation with commercial formulations are warranted to strengthen clinical and industrial applicability.

Conclusion and Future Prospects

A mild herbal shampoo containing selected botanical extracts was successfully formulated and evaluated. The formulation demonstrated satisfactory physicochemical properties, effective cleansing action, and acceptable foam characteristics, supporting its potential as a safer and eco-friendly alternative to conventional shampoos. Future work may include long-term stability studies, microbial challenge tests, and clinical evaluation on human volunteers.

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