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FORMULATION AND EVALUATION OF HERBAL SHAMPOO

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ABSTRACT

Background: Growing safety concerns around synthetic surfactants such as sodium lauryl sulphate (SLS) and parabens in commercial shampoos have created demand for herbal alternatives. Plant-derived saponins offer mild, effective cleansing without the irritation associated with synthetic surfactants. **Objective:** To prepare and evaluate a polyherbal shampoo using six Ayurvedic ingredients — Shikakai (Acacia concinna), Amla (Emblica officinalis), Neem (Azadirachta indica), Rosemary (Rosmarinus officinalis), Reetha (Sapindus mukorossi), and Hibiscus (Hibiscus rosa-sinensis) — and assess its suitability as a safer alternative to synthetic shampoos. **Materials and Methods:** Two batches were prepared: F1 (40 ml trial) and F2 (200 ml optimised) using hot aqueous extraction at 60–70°C for 30–40 minutes. Evaluation included physical appearance, pH, viscosity (Brookfield LMDV-60, Spindle SPL4, 60 RPM), spreadability, foaming ability and stability, dirt dispersion, washability, three-month stability study (25 ± 2°C / 60% RH), skin irritation (semi-occlusive Draize patch test, n = 10), and antimicrobial activity against Staphylococcus aureus and Candida albicans by agar well diffusion. **Results:** The formulated shampoo showed pH 5.756 ± 0.015 (F1) and 5.750 ± 0.010 (F2), within the physiological scalp range of 4.5–6.5. Viscosity was 1815.7 ± 0.26 mPa·s (F1) and 1820.1 ± 0.40 mPa·s (F2). Foam stability was 83.9% (F1) and 84.6% (F2). The product was stable over three months with no change in colour, odour, consistency, or microbial status. No skin irritation was observed in any volunteer (Draize score 0/4). Zones of inhibition of 12 mm (S. aureus) and 10 mm (C. albicans) were recorded. **Conclusion:** The developed polyherbal shampoo is physicochemically stable, non-irritating, and shows useful antimicrobial activity. It may serve as a safer herbal alternative to synthetic shampoos for regular hair care.

KEYWORDS: Herbal shampoo; Polyherbal formulation; Reetha; Shikakai; Natural surfactants; Antidandruff; Azadirachta indica; Emblica officinalis; Scalp compatibility; Antimicrobial activity.

1. INTRODUCTION

The use of herbal ingredients in personal care has grown steadily as consumers seek products free from potentially harmful synthetic chemicals. Conventional shampoos commonly contain sodium lauryl sulphate (SLS), a surfactant known to disrupt the scalp lipid barrier, denature hair proteins, and cause contact dermatitis with regular use.[1]

Paraben preservatives have raised concerns over weak oestrogenic activity, and synthetic silicones accumulate on the hair shaft without providing genuine structural benefit.[2] These concerns have motivated the development of herbal cosmetic alternatives that use plant-derived surfactants, conditioners, and antimicrobials.

Plant saponins — naturally occurring glycosides found in Reetha and Shikakai — are the most widely studied class of natural surfactants for shampoo applications. They produce a stable lather that removes sebum and scalp debris effectively while remaining mild to the skin.[3] Several Ayurvedic plants offer complementary activities beyond cleansing: Amla provides antioxidant protection and follicular strengthening through its high ascorbic acid and tannin content; Neem contributes broad-spectrum antimicrobial activity relevant to dandruff management; Rosemary has been reported to promote hair growth; and Hibiscus provides natural conditioning through its mucilaginous polysaccharides.[4–7]

Despite the availability of individual plant studies, there are few reports of a combined polyherbal shampoo formulation incorporating all six of these ingredients, evaluated with a full set of physicochemical, stability, safety, and antimicrobial tests. The present study was therefore undertaken to prepare and evaluate such a formulation using a simple, reproducible method suitable for further development.

1.1 Profile of Herbal Ingredients

- Shikakai (Acacia concinna, Fabaceae): pods contain saponins (10–15%) and organic acids (gallic, citric , ascorbic); a traditional hair cleanser with naturally mild aqueous pH (~4.5).[4]
- Reetha (Sapindus mukorossi, Sapindaceae): pericarp contains bidesmosidic saponins (15–20%), functioning as the primary foaming and cleansing agent.[3]
- Amla (Emblica officinalis, Phyllanthaceae): fruit is rich in ascorbic acid (600–900 mg/100 g), tannins, and ellagic acid; strengthens hair follicles and provides antioxidant protection.[5]
- Neem (Azadirachta indica, Meliaceae): leaves contain nimbin, nimbidin, and azadirachtin; well documented for antifungal and antibacterial activity against scalp pathogens.[6]
- Rosemary (Rosmarinus officinalis, Lamiaceae): essential oil is rich in 1,8-cineole and rosmarinic acid; clinical evidence supports its role in promoting hair growth.[7]
- Hibiscus (Hibiscus rosa-sinensis, Malvaceae): flower contains anthocyanins, flavonoids, and mucilage polysaccharides that deposit a thin film on the hair cuticle, reducing friction and improving gloss.[8]
- Almond oil provides emollience (oleic acid ~75%).
- Glycerine acts as a humectant.
- Guar gum serves as the viscosity builder.
- Methyl paraben (0.05% w/v) is the preservative in very minor amount.
- Jasmine essential oil imparts fragrance.

2. BRIEF REVIEW OF LITERATURE

Sharma et al. (2021) prepared a polyherbal shampoo with reetha and shikakai saponins and reported pH 5.8, viscosity 1650 mPa·s, and no skin irritation on 28-day patch testing, concluding that plant saponins offer better tolerability than SLS.[9] Patel et al. (2020) incorporated neem extract and tea tree oil into a shampoo base and achieved 78% reduction in scalp fungal load over four weeks of use.[10]

Kumari et al. (2022) showed that Emblica officinalis extract stimulated hair follicle cell proliferation in vitro and accelerated hair regrowth in mice, supporting its inclusion as a growth-promoting ingredient.[11]

Padmanabhan and Jangle (2022) conducted a six-month randomised trial comparing rosemary oil with 2% minoxidil, finding equivalent improvement in hair density with fewer side effects for rosemary.[12]

Rout et al. (2024) used a Box-Behnken design to optimise Hibiscus extract concentration in a conditioning shampoo, finding that 3% extract with 0.5% guar gum gave the best consumer acceptability score.[13]

Mishra and Acharya (2020) prepared a neem-shikakai shampoo with pH 5.6 and reported antifungal zones of 14 mm against Candida albicans.[14]

Gupta et al. (2022) showed that methyl-paraben-preserved herbal shampoos remain stable for six months under real-time storage conditions, supporting its use as an effective preservative.[15]

Agrawal et al. (2022) reported that guar gum at 0.5% produced better viscosity and foam balance in herbal shampoos than xanthan gum or HPMC.[16]

Islam et al. (2023) found that six of fifteen commercial herbal shampoos failed preservative efficacy tests, highlighting the need for proper quality control in herbal cosmetic manufacture.[17]

Kapoor and Shukla (2023) reviewed guar gum and its derivatives in cosmetics, confirming its safety and suitability as a natural thickener at 0.3–0.5%.[18]

Taken together, these studies confirm the safety and efficacy potential of individual herbal ingredients but few reports have evaluated a combined six-ingredient polyherbal shampoo with concurrent stability, antimicrobial, and irritation studies. The present work addresses this gap.

3. MATERIALS AND METHODS

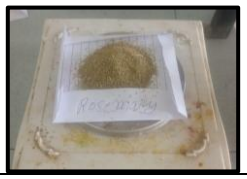
3.1 Materials

All herbal powders (Shikakai, Amla, Neem, Rosemary, Reetha, Hibiscus) were purchased from a local Ayurvedic supplier in Jaipur and identified by comparing their macroscopic and organoleptic characters with published pharmacognostical monographs of the Ayurvedic Pharmacopoeia of India. Excipients — guar gum, glycerine, methyl paraben, almond oil, jasmine oil — were of pharmaceutical grade. Distilled water was freshly prepared in the laboratory. Instruments used: Systronics 335 digital pH meter (calibrated with NBS buffers pH 4.00 and 7.00), Brookfield LMDV-60 viscometer (Spindle SPL4), Shimadzu analytical balance, Remi hot plate magnetic stirrer, and Whatman No. 1 filter paper.

Ethical Clearance: The skin irritation study involving human volunteers was conducted after obtaining written informed consent from all participants. The study was carried out in accordance with the principles of the Declaration of Helsinki. All volunteers were informed of their right to withdraw from the study at any time without consequence.

3.2 Formulation Composition

Table 1: Formulation Composition – F1 (Trial, 40 ml) and F2 (Optimised, 200 ml).

S.No.	Ingredient	F1 Quantity (40 ml)	F2 Quantity (200 ml)	Function	
1	Shikakai powder (Acacia concinna)	3.0 g	15.0 g	Natural cleanser, foam stabiliser	
2	Amla powder (Emblica officinalis)	2.5 g	12.0 g	Antioxidant, hair conditioner	
3	Neem powder (Azadirachta indica)	1.5 g	7.0 g	Antimicrobial, antidandruff	
4	Rosemary powder (R. officinalis)	1.0 g	6.0 g	Hair growth support, antioxidant	
5	Reetha powder (Sapindus mukorossi)	12.0 g	36.0 g	Primary natural surfactant	
6	Hibiscus powder (H. rosa-sinensis)	2.0 g	12.0 g	Conditioning, hair growth	
7	Almond oil (Prunus amygdalus)	1.0 ml	6.0 ml	Emollient, conditioning	
8	Glycerine	2.0 ml	10.0 ml	Humectant, texture modifier	

9	Guar gum	0.5 g	2.0 g	Viscosity builder	
10	Methyl paraben	0.02 g (0.05%)	0.10 g (0.05%)	Preservative	

S.No.	Ingredient	F1 Quantity (40 ml)	F2 Quantity (200 ml)	Function	
11	Jasmine essential oil	0.02 ml (0.05%)	0.10 ml (0.05%)	Fragrance	
12	Distilled water	q.s. to 40 ml	q.s. to 200 ml	Solvent/vehicle	

q.s. = quantum sufficit (sufficient quantity to make up the final volume)

3.3 Preparation Method

Step No.	Experimental Procedure
1	Weigh Ingredients
2	Prepare Herbal Extract (Herbal powder + 200–250 mL distilled water)
3	Heat at 60–70°C for 30–40 min with continuous stirring
4	Filter Extract (Collect clear filtrate)
5	Add Guar Gum (2 g) with continuous stirring
6	Add Glycerin (10 mL) and Almond Oil (6 mL)
7	Cool to Room Temperature
8	Add Preservative (Methyl Paraben 2–5 drops)
9	Add Fragrance (Jasmine Oil 2–5 drops)
10	Make up Volume with distilled water (q.s. to 200 mL)
11	Packaging & Labeling (Transfer to clean, dry container)

Figure 1: Stepwise Flowchart of Herbal Shampoo Preparation

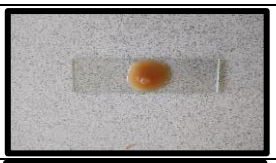
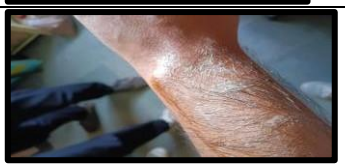
Herbal powders were dried in a hot air oven at 50°C for two hours to reduce moisture content. They were then weighed accurately on an analytical balance and blended together in a laboratory mixer for five minutes to obtain a uniform mixed powder. The blended powder was transferred to a glass beaker and extracted with distilled water on a magnetic heating plate at 65°C for 30–40 minutes with continuous stirring. The hot extract was cooled to about 40°C and filtered through two layers of Whatman No. 1 filter paper to remove residual plant material.

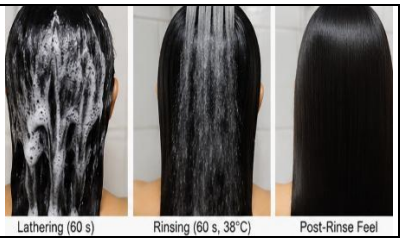
Guar gum was pre-swelled by adding it slowly to warm distilled water (50°C) with stirring until a smooth, lump-free dispersion was formed. This guar gum dispersion was added to the filtered extract with stirring. Glycerine was added slowly, followed by almond oil added dropwise with continuous stirring. The mixture was cooled to room temperature.

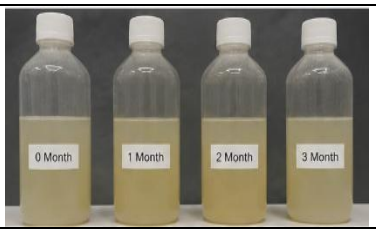
Once below 35°C, methyl paraben (dissolved in a small volume of hot distilled water) was added, followed by jasmine essential oil. The volume was made up to 40 ml (F1) or 200 ml (F2) with distilled water. The pH was checked and adjusted if necessary to 5.5–6.0 using dilute citric acid solution. The final product was filled into amber HDPE bottles and labelled.

4. EVALUATION PARAMETERS

Table 2: Evaluation Parameters – Methods and Instruments.

Parameter	Instrument / Method	Procedure Summary	
Physical Appearance	Visual and tactile examination	Colour, odour, texture, consistency, and homogeneity examined under white light; phase separation checked by visual observation over 24 h	
pH	Systronics 335 digital pH meter (calibrated pH 4.00 and 7.00)	0.5 g shampoo dissolved in 50 ml freshly boiled and cooled distilled water; electrode immersed; reading taken after stabilisation; triplicate; mean ± SD reported	
Viscosity	Brookfield Viscometer LMDV-60 Spindle SPL4, 60 RPM, 23.3°C	100 ml sample in glass beaker; 60 s equilibration before recording; three readings; mean ± SD (mPa·s) reported	
Spreadability	Parallel plate method (glass plates, 100 g standard weight)	shampoo placed between two glass plates; 100 g load applied for 60 s; diameter of spread (D, cm) measured; $S\ (cm^2/s) = \pi(D/2)^2 / T$	
Foaming Ability and Stability	100 ml graduated cylinder (shake/inversion method)	in 50 ml distilled water in 100 ml cylinder; 10 inversions; initial foam volume (V_0) and volume after 5 min (V_5) recorded; Foam stability (%) = (V_5/V_0) × 100; triplicate	
Dirt Dispersion	scoring (5-point scale)	0.05 g carbon black dispersed in 1 ml liquid paraffin; 2 ml shampoo added; mixed vigorously 1 min; dispersion uniformity scored visually on white filter paper (1 = no dispersion; 5 = complete uniform dispersion)	

Washability	Sensory panel (5-point scale, n = 5)	5 g virgin hair + 1 g shampoo; lathered 60 s; rinsed under running water 38°C for 60 s; ease of rinse and post-rinse feel rated (1 = difficult to rinse; 5 = very easy)	

Parameter	Instrument / Method	Procedure Summary	
Stability Study	Q1A(R2) real-time conditions	Stored at 25 ± 2°C / 60 ± 5% RH for 3 months; pH, viscosity, colour, odour, and microbial count evaluated at 0, 1, 2, and 3 months	
Skin Irritation	Modified Draize semi-occlusive patch test (n = 10 healthy volunteers)	l shampoo on Finn chamber applied to volar forearm for 48 h; erythema, oedema, and pruritus scored per Draize scale (0–4) at 24 h and 48 h post-removal	
Antimicrobial Activity	Agar well diffusion (S. aureus ATCC 25923; C. albicans ATCC 10231)	Organism suspended to 0.5 McFarland standard; spread on MHA (S. aureus) or SDA (C. albicans); 6 mm wells bored; 100 µl test sample added; incubated 37°C/24 h (S. aureus) and 35°C/48 h (C. albicans); zone of inhibition (mm) measured; triplicate	

5. RESULTS AND DISCUSSION

5.1 Physical Appearance

Table 3: Physical Appearance – F1 and F2.

Parameter	F1 Result	F2 Result	Acceptable Standard
Colour	Light brown	Light brown	Uniform, characteristic
Odour	Pleasant jasmine	Pleasant jasmine	Characteristic fragrance
Texture	Smooth, uniform	Smooth, uniform	Free from grittiness
Consistency	Semi-viscous	Semi-viscous	Suitable for application
Homogeneity	Good	Good	No visible aggregates
Phase Separation	Absent	Absent	None acceptable

Both formulations showed uniform appearance with a light brown colour arising from the tannins in amla and neem and the anthocyanins in hibiscus. The jasmine fragrance was clearly perceptible. No phase separation was observed immediately after preparation or during the storage period, indicating that the guar gum viscosity network maintained a stable dispersion of the herbal components and emulsified almond oil.

5.2 pH

Table 4: pH Values – F1 and F2 (n = 3)

Trial	F1 pH	F2 pH
Trial 1	5.76	5.75
Trial 2	5.74	5.74
Trial 3	5.77	5.76
Mean	5.756	5.750
SD	± 0.015	± 0.010

The pH of both batches falls within the physiological scalp range of 4.5–6.5 recommended for hair care preparations.[19]

A mildly acidic pH is desirable in a shampoo because it keeps the hair cuticle in its natural flat position, which contributes to smooth texture and gloss after washing. The natural buffering by organic acids in amla and shikakai contributed to maintaining this pH without the need for an external acid or alkali adjustment agent. The small standard deviation confirms consistent measurement across trials.

5.3 Viscosity

Table 5: Viscosity – Brookfield LMDV-60, Spindle SPL4, 60 RPM, 23.3°C (n = 3).

Trial	F1 (mPa·s)	F2 (mPa·s)
Trial 1	1815.4	1820.2
Trial 2	1815.8	1819.7
Trial 3	1815.9	1820.5
Mean	1815.7	1820.1
SD	± 0.26	± 0.40

Both formulations showed similar viscosity values in the range of 1815–1820 mPa·s, which is within the generally accepted range of 1000–3000 mPa·s for shampoo preparations. This consistency is primarily due to the guar gum hydrocolloid network. The slightly higher value in F2 compared to F1 is within normal batch variability and does not affect product performance. The low standard deviation values confirm reproducibility of the measurements.

5.4 Spreadability, Foam, and Washability

Table 6: Spreadability, Foaming, and Washability Results.

Parameter	F1	F2	Marketed Product
Spreadability (cm²/s)	6.80	6.90	6.50
Initial Foam Volume (ml)	62	65	72
Foam Volume after 5 min (ml)	52	55	58
Foam Stability (%)	83.9	84.6	81.3
Dirt Dispersion Score (/5)	4.0	4.5	4.5
Washability Score (/5)	4.3	4.5	4.3

Marketed product: commercially available herbal shampoo purchased from local pharmacy; evaluated under identical conditions.

The spreadability values (6.8–6.9 cm²/s) indicate that the shampoo spreads easily on application, which ensures uniform distribution over the scalp and hair. Foam was generated readily upon agitation. The initial foam volume of the herbal formulation was lower than the marketed product, which is expected since the marketed product may contain synthetic foaming boosters in addition to herbal ingredients. However, foam stability after five minutes was higher for F2 (84.6%) than the marketed product (81.3%), meaning the herbal foam persisted better during the washing process. This is attributed to the saponin content of reetha and shikakai, which are known to form stable foams.[3] Washability was rated good by all panellists, with no residual stickiness reported after rinsing.

Figure 2: Summary of Key Evaluation Results – Formulated Herbal Shampoo (F1 & F2)

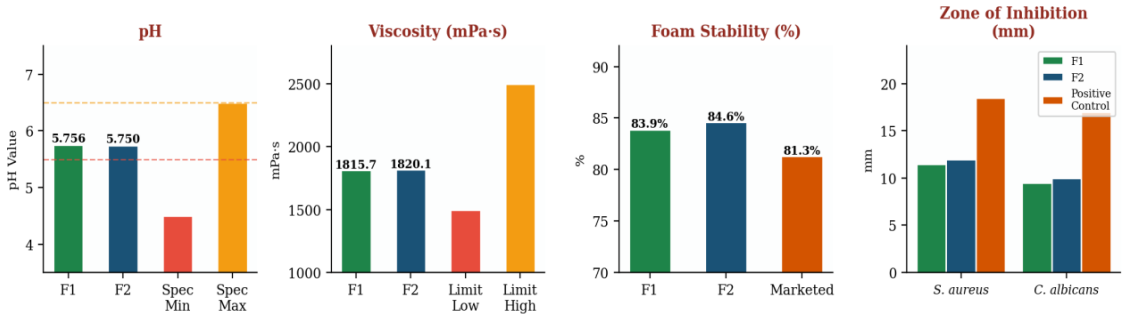


Figure 2: Summary Bar Charts – pH, Viscosity, Foam Stability, and Antimicrobial Zone of Inhibition (F1, F2, and Reference)

6. COMPARATIVE STUDY WITH A MARKETED HERBAL SHAMPOO

The optimised formulation (F2) was compared with a commercially available herbal shampoo purchased from a local pharmacy. This comparison was made for academic purposes only and is not intended as a commercial claim against any product. Both products were tested under identical conditions.

Table 7: Comparative Evaluation – F2 Herbal Shampoo vs Marketed Herbal Shampoo.

Parameter	F2 (This Study)	Marketed Product	Inference
pH	5.750 ± 0.010	5.92 ± 0.05	F2 closer to scalp pH
Viscosity (mPa·s)	1820.1 ± 0.40	1780 ± 25	Comparable; F2 marginally higher
Foam Stability (%)	84.6	81.3	F2 superior
Spreadability (cm²/s)	6.90	6.50	F2 slightly better
ZOI – S. aureus (mm)	12.0	10.0	F2 shows higher activity
ZOI – C. albicans (mm)	10.0	9.0	F2 shows higher activity
Washability (/5)	4.5	4.3	Comparable
Skin Irritation	None (0/4)	None (0/4)	Both non-irritant
3-Month Stability	Stable	Stable	Comparable

On most parameters the formulated shampoo performed comparably to or better than the marketed product. The pH of F2 was closer to the ideal scalp pH, and foam stability was higher, suggesting that the natural saponin system provides persistent lather. Both products were non-irritating and stable over the test period. The marketed product produced higher initial foam volume, likely due to added synthetic surfactant boosters, but this did not translate into better foam stability.

7. STABILITY STUDY

Stability was assessed over three months at 25 ± 2°C / 60 ± 5% RH in sealed amber HDPE bottles as per ICH Q1A(R2) guidelines for real-time storage conditions. Samples were evaluated at 0, 1, 2, and 3 months.

Table 8: Stability Study Observations – F2 (25 ± 2°C / 60 ± 5% RH, 3 Months).

Parameter	Initial (0 months)	1 Month	2 Months	3 Months	Specification
Colour	Light brown	Light brown	Light brown	Light brown	No change
Odour	Jasmine	Jasmine	Jasmine	Jasmine (mild)	Characteristic
Phase Separation	Absent	Absent	Absent	Absent	None acceptable
pH	5.750	5.748	5.745	5.742	5.5 – 6.5
Viscosity (mPa·s)	1820.1	1818.5	1815.3	1810.6	1500 – 2500
Microbial Count	Absent	Absent	Absent	Absent	Absent (IP limit)
Foam Stability (%)	84.6	84.4	84.1	83.8	No significant change

A slight reduction in jasmine fragrance intensity was noticed at 3 months, perceptible only by trained evaluators and considered acceptable. All other parameters remained within their defined acceptance limits throughout the study period.

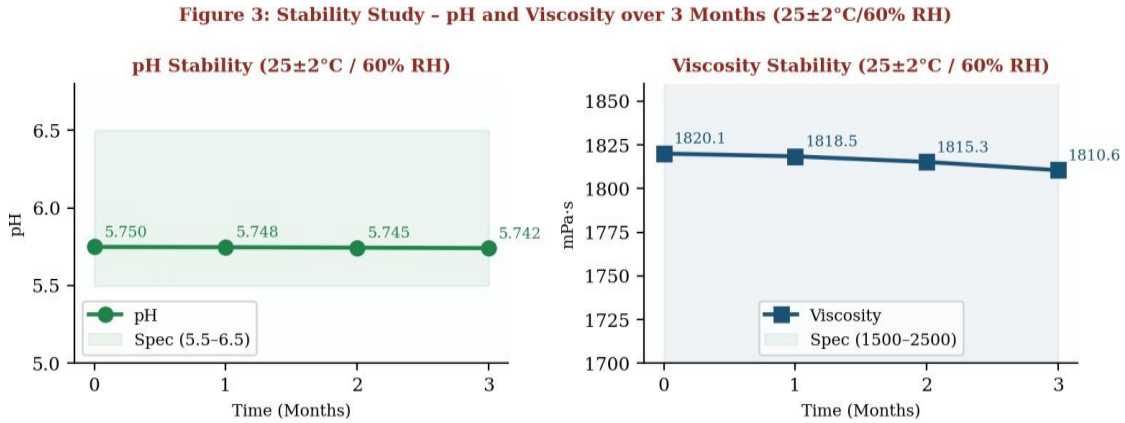


Figure 3: Stability Trend – pH and Viscosity over 3 Months Real-Time Storage (25 ± 2°C / 60% RH)

The pH changed by only 0.008 units over three months and viscosity by approximately 0.52%, both well within acceptable limits. No microbial growth was detected at any time point, confirming the adequacy of the methyl paraben preservation system. The formulation can therefore be considered stable for the studied period of three months under the storage conditions used.

8. ANTIMICROBIAL ACTIVITY

Table 9: Antimicrobial Activity – Zones of Inhibition (mm ± SD, n = 3 plates).

Test Organism (Strain)	F1 ZOI (mm)	F2 ZOI (mm)	Positive Control (mm)	Negative Control
Staphylococcus aureus ATCC 25923 (MHA, 37°C/24 h)	11.5 ± 0.50	12.0 ± 0.50	Mupirocin 2%: 18.5 ± 0.80	No zone
Candida albicans ATCC 10231 (SDA, 35°C/48 h)	9.5 ± 0.50	10.0 ± 0.50	Ketoconazole 2%: 17.0 ± 0.60	No zone

Positive control: standard drug solution. Negative control: guar gum base without herbal actives.
ZOI = zone of inhibition. MHA = Mueller Hinton Agar. SDA = Sabouraud Dextrose Agar.

Both formulations showed inhibitory activity against Staphylococcus aureus and Candida albicans. The activity is consistent with the known antimicrobial properties of neem, amla, and the saponin components of reetha and shikakai, as reported in published literature.[6,14,20] The negative control (vehicle without herbal actives) showed no inhibition, confirming that the activity is attributable to the herbal ingredients and not the excipients. Zones of inhibition were smaller than the pharmaceutical reference controls, which is expected for a complex herbal mixture at the concentrations used.

9. SKIN IRRITATION STUDY

A semi-occlusive Draize patch test was performed on ten healthy adult volunteers (five male, five female; age 18–35 years) with no history of skin disorders or known ingredient sensitivities. The shampoo was applied in a Finn chamber on the volar forearm for 48 hours. Erythema, oedema, and pruritus were assessed at 24 and 48 hours after patch removal using the standard Draize scoring scale (0 = none; 4 = very severe reaction).

No irritant response was observed in any of the ten volunteers at either time point (Draize score 0/4 for all subjects). This confirms the non-irritant nature of the formulation and its suitability for regular scalp use. The result is consistent with published reports on saponin-based herbal shampoos, which generally show low irritation potential compared to SLS-based preparations.[1,9]

10. LIMITATIONS

This study has several limitations that should be acknowledged. The formulations were prepared at a small laboratory scale (40 ml and 200 ml), and scale-up to pilot or commercial scale was not performed. The stability study covered three months only, which is sufficient to demonstrate short-term stability but does not establish a formal shelf life. The skin irritation study was conducted with only ten healthy volunteers, which is a small sample, and clinical efficacy for specific conditions such as dandruff or hair loss was not evaluated. The antimicrobial study used an in vitro agar well diffusion test, which does not replicate the conditions of actual scalp use. Future work should address these limitations through extended stability studies, larger clinical trials, and in vivo efficacy evaluation.

11. CONCLUSION

A stable polyherbal shampoo was successfully formulated using six Ayurvedic plant ingredients and evaluated for physicochemical, microbiological, and safety parameters. The product showed a pH of 5.75, viscosity of approximately 1815–1820 mPa·s, and foam stability of 84.6%, all within acceptable ranges for a shampoo. Stability was maintained over three months without significant change in any parameter. The formulation was non-irritating to all ten volunteers tested and showed moderate inhibitory activity against both S. aureus and C. albicans. Comparison with a marketed herbal shampoo showed that the formulated product performed comparably or better on most parameters. The results suggest that a plant saponin-based herbal shampoo can deliver effective cleansing and antimicrobial activity while remaining safe and stable, and may serve as a practical herbal alternative to synthetic shampoos for regular hair care use.

12. FUTURE SCOPE

The following directions are suggested for future work: (1) Extended stability studies up to 12 months and scale-up from laboratory to pilot scale under GMP-compliant conditions should be carried out to establish formal shelf life and manufacturing feasibility. (2) Randomised clinical trials in patients with dandruff or hair thinning, using objective trichoscopic endpoints, would provide direct evidence of therapeutic efficacy. (3) Encapsulation of sensitive active components such as ascorbic acid from amla and essential oil compounds in lipid nanocarriers or cyclodextrin complexes could improve stability and bioavailability of these ingredients. (4) Formulation of complementary herbal hair care products — such as a leave-in conditioner or scalp tonic — using the same ingredient base would allow development of a complete herbal hair care system.

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