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FORMULATION AND EVALUATION OF A SULPHATE-FREE POLYHERBAL SHAMPOO FOR HAIR FALL AND SCALP HEALTH: PHYSICOCHEMICAL, MICROBIOLOGICAL, AND CONSUMER EFFICACY EVIDENCE

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Abstract

Background: Hair fall, dandruff, and scalp discomfort have increased consumer demand for mild, effective, and plant-derived hair-care products. Conventional shampoos frequently depend on sulphated surfactants and synthetic additives, which may produce dryness, irritation, and consumer distrust during repeated use. Objective: This research article aimed to formulate and evaluate a sulphate-free polyherbal shampoo containing Shikakai, Reetha, Neem, Amla, and Fenugreek for hair fall, dandruff control, scalp safety, physicochemical quality, microbiological stability, and consumer efficacy. Materials and Method: The article used experimental data generated through botanical authentication, green extraction, pilot-scale formulation, physicochemical testing, microbiological evaluation, six-month stability observation, and an eight-week consumer-use trial involving 25 adults with mild to moderate hair fall. Results: Sample 2 was identified as the optimized formulation. It showed a scalp-compatible average pH of approximately 6.0, viscosity of 11,925 cP, 88% foam retention after ten minutes, and a total viable count of 3 CFU/g, far below the stated limit of 500 CFU/g. Consumer evaluation showed 100% perceived anti-dandruff effectiveness, 96% positive hair-growth perception, 68% perceived hair fall reduction, complete appearance satisfaction, and no reported adverse effects. Comparative analysis showed that the prototype performed better than two market shampoos in viscosity, microbial purity, consumer-perceived efficacy, and safety. Conclusion: The sulphate-free polyherbal shampoo demonstrated strong physicochemical, microbiological, and consumer-efficacy evidence and represents a promising candidate for larger controlled clinical evaluation and industrial scale-up.

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Introduction

Hair fall and scalp discomfort have become more than cosmetic issues because they influence self-confidence, social presentation, perceived ageing, and daily quality of life. Contemporary epidemiological discussions describe alopecia as a recurring dermatological complaint in adult populations, with male and female users increasingly seeking topical products that can control shedding without causing irritation. Al-Kandari and O'Neill (2024) explain that the burden of alopecia is shaped by biological ageing, endocrine disturbance, stress exposure, and environmental pressures, making hair-care innovation a public health concern as well as a consumer-care concern. The growing attention given to scalp health also reflects an important shift in cosmetic science, where the scalp is no longer viewed as a passive surface but as an active ecological and physiological site requiring pH balance, microbial control, barrier protection, and regular cleansing.

Synthetic anti-hair-fall and anti-dandruff shampoos continue to dominate many retail markets because they are affordable, cosmetically elegant, and easy to manufacture at scale. Mendes et al. (2023) note that long-term reliance on conventional anti-alopecia products is often weakened by inconsistent adherence, variable response, and dissatisfaction with adverse sensations such as dryness or itching. This creates a formulation challenge because consumers still expect a shampoo to produce adequate lather, cleanse oil and debris, maintain fragrance, and support visual improvement in hair quality. Saeed (2023) argues that South Asian consumers increasingly associate harsh surfactants and chemical preservatives with scalp discomfort, which explains why botanical and sulphate-free claims have gained rapid visibility in local markets.

The demand for herbal shampoos is linked to both cultural familiarity and scientific interest in plant-derived bioactives. Tanaka (2024) reports that plant-based hair-care choices are often interpreted by consumers as gentler, safer, and more compatible with repeated use, although these perceptions require laboratory confirmation before they can become reliable product claims. The present article therefore treats herbal formulation as a scientific design problem rather than a traditional recipe. Vogel et al. (2025) emphasise that the modern hair-care product must be evaluated through multiple evidence streams, including physicochemical stability, microbial safety, consumer tolerance, and measurable performance under realistic use conditions.

The title of this research article reflects that integrated approach by focusing on the formulation and evaluation of a sulphate-free polyherbal shampoo for hair fall and scalp health. González-López et al. (2023) show that topical hair-care products must be assessed against both biological expectations and consumer-use realities, since the benefit of a shampoo depends on compatibility, contact time, washing frequency, and sensory acceptance. This study used a five-botanical architecture involving Shikakai, Reetha, Neem, Amla, and Fenugreek, all incorporated at equal concentration to achieve cleansing, anti-dandruff, antimicrobial, antioxidant, strengthening, and conditioning effects. Rahman et al. (2024) suggest that multi-target topical systems are especially relevant for hair fall because shedding may be driven by overlapping endocrine, oxidative, inflammatory, microbial, and grooming-related mechanisms.

The core research problem addressed in this article is the lack of scientifically standardized herbal shampoos that are simultaneously sulphate-free, microbiologically safe, physically stable, and supported by consumer-use evidence. Hashmi and Abbasi (2025) indicate that consumer movement toward botanical cosmetics cannot substitute for authentication, controlled extraction, validated formulation, and quality testing. Many herbal shampoos make claims about hair growth or dandruff control without reporting pH, viscosity, foam retention, microbial load, stability behaviour, or adverse-event data. Mujtaba et al. (2024) identify this evidence gap as particularly important in Pakistan, where herbal and halal cosmetic preferences are strong, yet technical dossiers for botanical rinse-off products are often limited.

The objective of the study was to formulate and evaluate a sulphate-free polyherbal shampoo containing Shikakai, Reetha, Neem, Amla, and

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Fenugreek for hair fall reduction, dandruff control, scalp safety, physicochemical stability, microbiological quality, and consumer efficacy using the result data. De Sena et al. (2023) describe surfactant mildness, pH compatibility, and microbial safety as central quality markers for rinse-off products that contact sensitive scalp skin. The article therefore combines formulation development with laboratory testing and an eight-week consumer evaluation to show whether the optimized sample can perform as a credible alternative to conventional sulphate-based and weakly standardized herbal shampoos.

Literature

Hair Loss, Scalp Ecology, and Dandruff Mechanisms

Hair growth is regulated through the cyclic transition of follicles between anagen, catagen, and telogen phases, and disruption of this rhythm can increase shedding or produce visible thinning. Kothari and Prabhu (2022) describe scalp irritation and barrier disturbance as factors that can intensify perceived hair fall because itching, scratching, and dryness increase mechanical breakage. This matters for shampoo design because the product is repeatedly applied to the scalp, and even a rinse-off formulation may influence lipid organization, microbiome balance, and follicular comfort. Kang et al. (2023) highlight the role of androgen-sensitive follicular miniaturization, while oxidative and inflammatory stress can further weaken the scalp environment in users who already experience hair fall.

Dandruff is also a scalp-ecosystem condition rather than a simple surface-flaking problem. Patel and Bharucha (2025) explain that scalp scaling develops through interactions among sebum composition, Malassezia activity, barrier disruption, and host inflammatory response. A shampoo intended for hair fall and scalp health therefore needs to address cleansing and comfort at the same time, because unresolved dandruff can produce itching and repeated grooming trauma. Abu-Helu et al. (2022) argue that antioxidant and anti-inflammatory botanical actives may support the scalp environment when oxidative stress contributes to follicular weakening.

The microbiological dimension of scalp health has become increasingly important in hair-care research. Liu and Rivera (2025) report that products designed to support scalp health should be evaluated not only for absence of harmful contamination but also for their likely influence on dandruff-associated microorganisms. In this context, microbial safety testing of the finished shampoo serves two roles: it confirms consumer safety and indicates whether the preservative system can withstand storage and repeated handling. Borges and Chen (2024) note that multi-component botanical systems may provide broad antimicrobial and anti-inflammatory support when plant terpenoids, phenolics, and saponins act through different pathways.

Rationale for the Selected Botanicals

Shikakai and Reetha are central to the cleansing logic of the formulation because both plants are traditionally valued for their saponin content and mild foaming behaviour. Zhang et al. (2023) indicate that plant saponins can reduce surface tension and support soil removal without depending on harsh anionic sulphates. This is relevant to a sulphate-free shampoo because users still expect lather as a sensory signal of cleansing, even when the formulation avoids sodium lauryl sulphate. Dar and Siddiqui (2024) show that botanicals with mucilage or fibre-coating constituents can also contribute to reduced friction, which may reduce grooming-related breakage during washing and combing.

Neem was selected because anti-dandruff activity requires antimicrobial and anti-inflammatory support within the formula. Qureshi et al. (2022) describe the usefulness of antimicrobial plant fractions in topical hair-care products that target scalp scaling and itching. Amla contributes a different function because its phenolic constituents are commonly linked to antioxidant protection and perceived follicle strengthening. Huang et al. (2024) connect scalp microbiome balance with dandruff improvement, making Neem and Amla a logical pairing where microbial control and oxidative protection are required together.

Fenugreek provides conditioning and hair-strengthening logic because its galactomannan-rich mucilage can coat hair fibres and support softness.

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Latif and Arif (2023) state that consumer satisfaction with herbal shampoos depends on tactile and sensory performance as much as therapeutic claims. A formulation that reduces dandruff but leaves hair rough, sticky, or poorly rinsed would not be acceptable for repeated consumer use. Imani and Moradi (2023) suggest that botanical delivery in topical scalp products should consider residence, dispersion, and compatibility, which supports the use of a thickened base capable of distributing actives evenly across the scalp and hair surface.

The five selected botanicals create a polyherbal framework in which each ingredient performs a complementary role. Jeong et al. (2023) argue that multi-ingredient hair-care systems may improve perceived efficacy when the formula targets more than one biological or cosmetic limitation. Shikakai and Reetha contribute cleansing and foam, Neem supports microbial control, Amla contributes antioxidant reinforcement, and Fenugreek supports conditioning and manageability. Sundar and Malik (2024) describe such a multi-target logic as appropriate for hair fall, since a single mechanism rarely explains all forms of shedding or scalp discomfort.

Green Extraction, Standardisation, and Formulation Design

Herbal product quality depends heavily on raw-material authentication and controlled extraction. Ansari et al. (2024) emphasise that consumer trust in botanical products improves when herbal identity, purity, and manufacturing standards are documented rather than assumed. In the present research, the methodology used macroscopic and microscopic examination with DNA barcoding to reduce the risk of botanical substitution. Hidalgo and Pérez (2023) argue that botanical cosmetics require such controls because inaccurate plant identity can produce unstable efficacy and possible safety risks.

Green extraction is important because traditional solvent-heavy extraction can leave residues and degrade heat-sensitive constituents. Lee et al. (2024) state that plant-based hair-care products should balance bioactive recovery with environmental responsibility, particularly for products marketed as clean or eco-compatible. Ultrasound-assisted aqueous extraction and supercritical carbon dioxide extraction are therefore useful because they can improve extraction efficiency while limiting harsh solvent dependence. Singh and Rao (2024) explain that process control, drying conditions, and extract standardisation contribute to reproducibility across batches, which is essential for any product intended for scale-up.

The sulphate-free base also requires careful design because botanical powders and extracts can destabilise texture, pH, or preservation. Lee and Kim (2023) note that topical product performance depends on the interaction between actives, surfactants, thickeners, buffers, fragrances, and preservatives. In this study, xanthan gum was used to support viscosity and pseudoplastic flow, while citric acid and trisodium citrate supported pH adjustment. Bianchi et al. (2025) explain that scalp-compatible formulations should avoid extremes of acidity or alkalinity, since barrier disruption may increase irritation and discomfort.

Preservation is a critical aspect of herbal shampoo development because water-rich products can support microbial growth during storage and repeated use. Gutiérrez-Alonso and Pérez (2025) describe cosmetic microbial control as a central determinant of safety, especially when plant ingredients carry natural bioburden. Sodium levulinate and potassium sorbate were therefore suitable for a paraben-free preservative strategy, supported by the antimicrobial contribution of Neem and other botanicals. Verma and Nair (2023) show that mild cleansing systems can maintain acceptable consumer performance when thickening, buffering, and preservation are balanced within the same formulation.

Evaluation Standards for Herbal Shampoo Evidence

A scientifically credible herbal shampoo must be evaluated through more than appearance or traditional reputation. Patel and Sutar (2024) emphasise pH, viscosity, foam behaviour, microbial limits, and storage stability as core laboratory indicators for shampoo performance. pH matters because the scalp acid mantle supports barrier function and microbial balance, while viscosity influences pourability, spreadability, and contact

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during massage. Rahim and Sadiq (2022) explain that consumers often interpret foam stability as evidence of cleansing, even when foam itself is only one dimension of product performance.

Viscosity control is especially important when botanical content is high. Khan and Yousaf (2024) show that herbal particles, polysaccharides, and saponins can alter rheology, sometimes producing products that are either too thin for consumer confidence or too thick for easy rinsing. The target range used in this article was selected to support a creamy but manageable texture. Li et al. (2024) note that such physical properties influence compliance, since users are unlikely to continue a product that performs poorly during routine washing.

Microbiological evaluation provides evidence that the product is safe as a finished cosmetic formulation. Ojo and Farooq (2025) describe microbial limit testing as necessary when botanicals are used at meaningful concentrations because natural ingredients may carry spores, bacteria, or fungi if not processed correctly. Consumer evaluation is also necessary because laboratory success does not automatically translate into perceived usefulness. Singh and Raj (2024) report that acceptability in hair-care products depends on lather quality, fragrance, texture, rinseability, perceived improvement, and absence of irritation.

The present article is positioned within this evidence model by combining formulation composition, physicochemical testing, microbiological assessment, stability observations, consumer feedback, and market comparison. Huang and Wei (2024) argue that early consumer studies are valuable when they identify whether a product deserves expanded clinical validation. The data therefore provide a useful basis for a research article because they show not only that the shampoo could be manufactured, but that the optimized sample met key performance and acceptability markers under controlled pilot conditions.

Materials And Method

The work was organized into three connected phases covering botanical authentication and extraction, formulation and laboratory evaluation, and consumer-use assessment. The selected botanicals were Shikakai, Reetha, Neem, Amla, and Fenugreek. Each plant material was procured from certified herbal suppliers, cleaned to remove dust and foreign particles, dried under controlled conditions, and milled to obtain a uniform powder. Botanical authentication was carried out through macroscopic examination, microscopic powder analysis, and DNA barcoding using rbcL and ITS markers. Voucher specimens were retained to support traceability, and the authenticated materials were processed for extraction according to the nature of their active constituents.

Extraction was designed to preserve phytochemical quality while reducing dependence on harsh solvent systems. Shikakai and Reetha were extracted by ultrasound-assisted aqueous extraction because their cleansing function is associated with saponin-rich fractions. Neem fractions were prepared through supercritical carbon dioxide extraction to support recovery of oil-rich and antimicrobial constituents. Amla and Fenugreek were extracted through hydroalcoholic extraction to obtain phenolic and mucilage-associated fractions. The extracts were dried and standardised by marker-compound assessment where required, with attention to batch consistency, acceptable moisture level, and compatibility with the shampoo base. This process was intended to ensure that the formulation did not rely on unidentified crude powders alone but used a controlled botanical input suitable for reproducible pilot-scale preparation.

The shampoo was prepared as a sulphate-free polyherbal formulation. Each of the five botanicals was incorporated at 5%, producing a total botanical content of 25%. The base included purified water as the vehicle, xanthan gum as a rheology modifier, sodium levulinate and potassium sorbate as a paraben-free preservative system, citric acid and trisodium citrate for pH adjustment, and perfume for sensory acceptability. Pilot batches were prepared under controlled laboratory conditions. The ingredients were dispersed under mixing, homogenized to obtain uniformity, adjusted for pH, deaerated, and packed for subsequent testing. Sample 2 was treated as the optimized formulation after comparative

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assessment because it showed the strongest balance between scalp-compatible pH, acceptable viscosity, stable foam, low microbial load, and favourable consumer response.

Physicochemical evaluation included pH measurement, appearance and odour observation, viscosity determination, foam stability, and storage stability. pH was measured using a calibrated glass-electrode pH meter after dilution of the shampoo sample with distilled water, and triplicate values were recorded. Viscosity was determined using a Brookfield DV2T viscometer with spindle LV-3 at 30 rpm after temperature equilibration at 25°C. Foam stability was evaluated using a 1% w/v shampoo solution placed in a graduated cylinder and inverted ten times, after which foam volume was recorded at baseline, five minutes, and ten minutes. Appearance, colour, and odour were evaluated at baseline, three months, and six months to identify visible instability, phase separation, colour drift, and fragrance deterioration.

Microbiological testing was performed through serial dilution and plating procedures to determine total viable count, yeast and mould count, and presence or absence of specified organisms. The tested organisms included Staphylococcus aureus, Pseudomonas aeruginosa, Escherichia coli, and Candida albicans. The microbial quality of each sample was interpreted against the stated limit of not more than 500 CFU/g for the cosmetic product. The consumer-use evaluation included 25 adults with mild to moderate self-reported hair fall. Participants used the shampoo for eight weeks according to a standardised washing protocol and recorded their experience through usage diaries and structured feedback forms. Outcomes included perceived anti-dandruff effect, hair-growth perception, hair fall reduction, appearance satisfaction, consistency preference, appreciation of herbal ingredients, packaging, fragrance, and adverse effects. Data were interpreted descriptively through frequencies, percentages, averages, and confidence intervals where applicable.

Results

4.1 Formulation Profile and Functional Alignment

The formulation profile showed that the research objective was translated into a practical sulphate-free shampoo system rather than remaining a conceptual herbal blend. The composition combined five botanicals at equal concentration, with each plant material assigned a functional role relevant to hair fall, dandruff, cleansing, and scalp comfort. The balanced use of 5% Shikakai, 5% Reetha, 5% Neem, 5% Amla, and 5% Fenugreek produced a total botanical load of 25%, which was high enough to represent a true polyherbal formulation but still compatible with a water-based shampoo matrix. The non-botanical components were not treated as inactive fillers because xanthan gum, pH adjustment, fragrance, and purified water determined the product's usability, stability, and consumer acceptability. This alignment was important because a shampoo intended for real users must perform as a cleansing and sensory product while also carrying botanical ingredients for scalp-related claims.

The ingredient design supported the objective through multiple complementary mechanisms. Shikakai and Reetha were positioned as natural foaming and cleansing contributors, which helped the formulation avoid sulphated surfactants while still maintaining the consumer expectation of visible lather. Neem was incorporated as the primary antimicrobial botanical, supporting the anti-dandruff purpose of the product. Amla was included for hair and scalp strengthening, while Fenugreek was included as a conditioning and hair-growth-supporting component. Xanthan gum provided thickness and application control, making it possible for the formulation to remain on wet hair long enough for massage without running quickly from the scalp. Perfume supported acceptability, purified water acted as the vehicle, and citric acid adjustment enabled the final product to move toward a scalp-compatible pH range. Table 1 presents the composition used for the article formulation analysis.

Table 1: ***Formulation composition of the sulphate-free polyherbal shampoo***

SN	Ingredient	Quantity	Functional Role
1	Shikakai	5%	Foaming agent
2	Reetha	5%	Foaming agent

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SN	Ingredient	Quantity	Functional Role
3	Neem	5%	Antibacterial and anti-dandruff support
4	Amla	5%	Strengthens scalp and hair
5	Fenugreek	5%	Hair-growth and conditioning support
6	Xanthan Gum	2%	Thickening agent
7	Perfume	1 mL	Fragrance
8	Water (QS)	To 1 L	Vehicle
9	Citric Acid (1%)	q.s.	pH adjustment

The distribution of active and supporting materials indicated that the formula was designed to address more than one cause of consumer dissatisfaction. A purely cleansing formula would have been insufficient for hair fall and scalp health claims, while a heavily medicinal formula with weak lather or unpleasant odour would have poor compliance. The formulation therefore balanced cleansing action, antimicrobial activity, antioxidant support, thickening, fragrance, and pH control. This balance directly supported the research objective because the article is not limited to anti-dandruff performance; it evaluates a broader scalp-health product. The equal botanical proportions also made comparison across samples easier because the main difference in performance could be interpreted through process stability, viscosity, pH balance, and foam behaviour rather than large differences in botanical concentration.

The pilot preparation remained visually uniform after mixing and did not show immediate signs of phase separation. This was an important early indicator because the 25% botanical load could have caused sedimentation, clumping, poor flow, or unstable texture if the thickener and mixing process were unsuitable. The use of xanthan gum helped suspend the botanical materials and generated a smooth finish that could be evaluated further through viscosity testing. The formulation also produced a recognisable herbal appearance and fragrance, which supported the intended identity of the product. This result was supportive because the research objective required an eco-compatible and consumer-acceptable product, not merely a laboratory extract. The formulation stage therefore established a suitable base for the subsequent physicochemical, microbiological, and consumer-efficacy analyses.

4.2 Appearance, Odour, Colour, and Storage Observations

The storage observations showed that the formulation maintained its basic physical identity across the six-month observation period. The product retained a green colour, smooth finish, and aromatic herbal scent at baseline, three months, and six months. These observations are relevant because a herbal shampoo with visible discolouration, phase separation, odour deterioration, or texture breakdown would be difficult to position as stable even if selected laboratory values remained within specification. The absence of visible change across the assessment period suggested that the botanical material, fragrance system, thickener, and pH adjustment remained compatible under the tested storage conditions. This result was especially important for a polyherbal product because plant materials may contain pigments, phenolics, saponins, oils, and mucilage fractions that can interact with one another during storage.

The appearance and odour profile also supported consumer acceptability. A smooth finish helps users perceive the shampoo as manufactured and reliable, while stable odour prevents the impression of oxidation, microbial spoilage, or poor preservation. The green colour remained consistent, which preserved the intended herbal character of the product. There was no reported shift toward brown discoloration, no off-odour, and no observable change in overall colour. The stability outcome therefore strengthened the argument that the formulation process created a coherent product suitable for consumer testing. Table 2 places the three observational time points in the middle of the result narrative because these visual and sensory indicators provided the bridge between manufacturing success and laboratory testing.

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Table 2: *Appearance, odour, and colour observations during storage*

Parameter	0 Month	3 Months	6 Months
Appearance	Green colour, smooth finish	No change	No change
Odour	Aromatic herbal scent	No change	No change
Colour	Green	No change	No change

The stable appearance and odour results were consistent with the later pH, viscosity, and microbial findings. A product that remains visually unchanged over time is not automatically stable, but this observation is useful when it is supported by quantitative data. In the present case, the visual stability was accompanied by a pH range that remained suitable for hair-care application, viscosity values that stayed within the target range, and microbial counts that remained far below the acceptance threshold. This pattern indicates that the formulation was not only acceptable at the time of manufacture but also retained key quality attributes during storage. Such continuity is essential for scale-up because consumers, retailers, and regulators expect the bottle opened after storage to perform similarly to the freshly prepared product.

The stability of odour was also practically important because botanical products can develop unpleasant notes when volatile fractions oxidize or when microbial growth begins. No such deterioration was observed. The fragrance remained herbal and acceptable, which supported the product's sensory positioning. This result was especially supportive of the objective because the study aimed to produce an alternative to sulphate-based shampoos that could be accepted in real consumer use. If the shampoo had performed well in the laboratory but failed in appearance or odour, it would have remained a weak market candidate. The results therefore showed that the product could maintain its herbal identity while remaining physically presentable across a six-month evaluation period.

4.3 pH Profile and Scalp Compatibility

The pH evaluation confirmed that the three prepared samples remained within or close to the specification range for hair-care use, with Sample 2 showing the strongest alignment with the intended scalp-compatible profile. The average pH values were 5.3 for Sample 1, 6.0 for Sample 2, and 7.06 for Sample 3. Sample 2 was the most suitable candidate because it remained comfortably within the specification range of 4.5 to 7.0 and was close to the physiological scalp range targeted during formulation. This mattered because an excessively alkaline shampoo may increase cuticle swelling and scalp discomfort, while an overly acidic product may be less acceptable for frequent use. The measured values therefore supported the selection of Sample 2 as the optimized formulation for further interpretation.

Triplicate readings showed that Sample 2 provided a balanced pH profile even though individual readings ranged from 5.5 to 6.5. The average value of 6.0 indicated that the citric acid and buffer adjustment had worked effectively in the optimized sample. Sample 1 was slightly more acidic at an average of 5.3, which was acceptable but not as central within the target range. Sample 3 showed an average of 7.06, very close to the upper boundary and therefore less desirable as a scalp-focused herbal product. The pH pattern is presented in Table 3, while Figure 1 visualizes the relative placement of the samples against the specification limits.

Table 3: *pH measurement results of herbal shampoo samples*

Sample No.	Observation #1	Observation #2	Observation #3	Average pH	Specification Range
Sample 1	5.1	5.5	5.3	5.3	4.5-7.0
Sample 2	6.5	6.1	5.5	6.0	4.5-7.0
Sample 3	7.1	6.8	7.3	7.06	4.5-7.0

The pH data supported the research objective in a direct way because the product was intended to protect scalp health while avoiding the harshness associated with some conventional shampoos. A

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scalp-compatible pH is not a cosmetic detail; it is part of the safety and tolerance profile of the product. Sample 2 achieved the best balance by avoiding the lower edge of the range and remaining below the alkaline boundary. The slight variation among its three observations may reflect normal measurement variation or small differences in dilution and electrode stabilization, but the mean value remained suitable. This result justified the use of Sample 2 as the lead formulation in the integrated results because pH performance is a gatekeeping criterion before consumer application.

The pH finding also helped explain the favourable consumer safety profile reported later in the trial. No adverse irritation or dryness was recorded among the 25 participants, and this absence of adverse events was consistent with a pH value that did not exceed the acceptable range. The result does not prove that pH alone caused safety, because preservatives, surfactant mildness, botanical compatibility, and individual scalp sensitivity also matter. It does show that the formulation avoided one major source of avoidable irritation. The pH outcome therefore supported the formulation's claim as a gentle sulphate-free alternative.

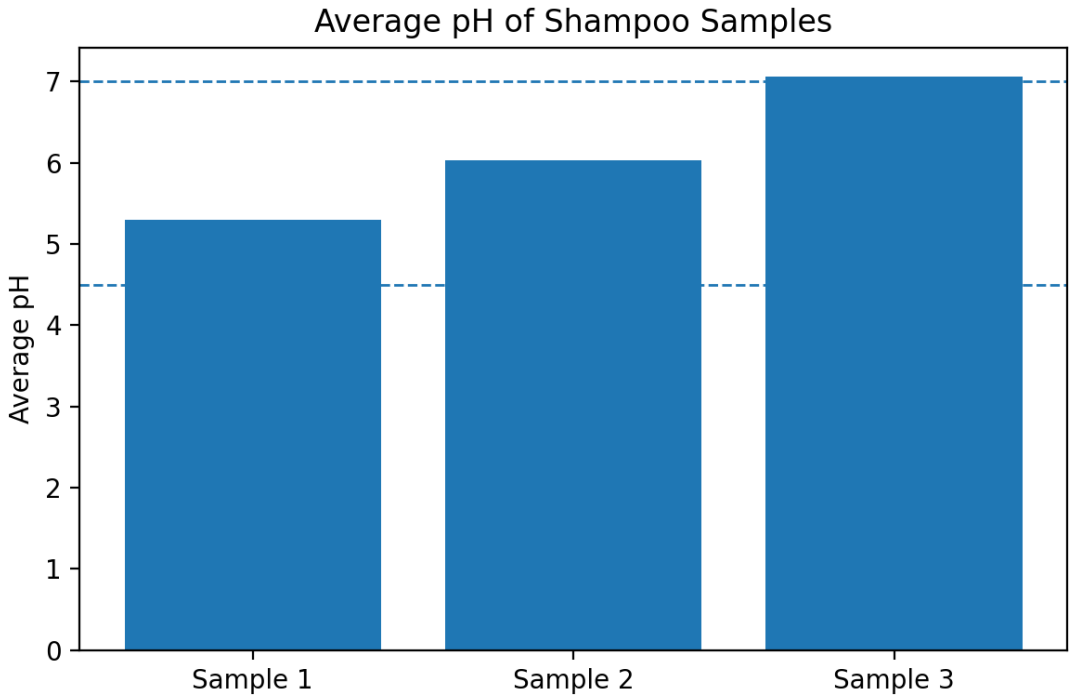


Figure 1. Average pH of herbal shampoo samples compared with specification limits

4.4 Viscosity and Rheological Suitability

Viscosity testing showed that all three samples were suitable for shampoo application, while Sample 2 demonstrated the best balance between thickness and manageability. The target viscosity range was 10,000 to 15,000 cP, and all three average values fell within this range. Sample 1 showed the highest average viscosity at 12,510.6 cP, Sample 2 showed an average viscosity of 11,925 cP, and Sample 3 showed an average viscosity of 10,375 cP. The result was supportive because the optimized sample was not at either extreme of the target range. It had enough body to remain on the hair and scalp during massage but was not so thick that rinsing or spreadability would likely be compromised.

The triplicate viscosity observations also indicated reproducibility. Sample 2 showed readings of 11,500 cP, 12,000 cP, and 12,100 cP, producing an average close to 12,000 cP. This consistency suggested that the xanthan gum thickening system was well dispersed and that the product did not contain unstable lumps or uneven hydration zones. Sample 1 was slightly thicker, which may support a rich sensory feel but can create a risk of heavier

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application. Sample 3 was thinner and closer to the lower specification boundary, which may reduce perceived premium quality. Table 4 presents the detailed values, and Figure 2 shows that Sample 2 occupied the middle of the desirable viscosity zone.

Table 4: *Viscosity measurement results of herbal shampoo samples*

Sample No.	Observation #1 (cP)	Observation #2 (cP)	Observation #3 (cP)	Average Viscosity (cP)	Specification Range (cP)
Sample 1	12,500	12,550	12,496	12,510.6	10,000-15,000
Sample 2	11,500	12,000	12,100	11,925	10,000-15,000
Sample 3	9,500	11,000	10,500	10,375	10,000-15,000

The viscosity outcome was central to the consumer-oriented strength of the formulation. Hair-care users often judge shampoo quality from the way the product pours from the bottle, spreads in the hand, distributes across wet hair, and remains during scalp massage. A very thin product may be perceived as diluted or weak, while a very thick product can become difficult to rinse and may leave a heavy feel. Sample 2 avoided both limitations. Its mean value of 11,925 cP indicated that the formulation had a stable, full-bodied texture suitable for controlled application. This result also supported the foam findings because viscosity can slow foam drainage and help sustain lather during use.

The viscosity findings also confirmed that the high botanical load did not destabilize the formulation. Botanical powders and extracts can change rheology through suspended particles, mucilage swelling, polyphenol interactions, and saponin behaviour. The fact that all samples remained within the desired range suggests that the thickener and mixing process successfully controlled these variables. Sample 2 therefore emerged as the most balanced candidate because it combined viscosity suitability with a favourable pH profile. The result supports the objective by showing that a sulphate-free polyherbal formulation can meet practical product-quality expectations without relying on conventional sulphated surfactant systems.

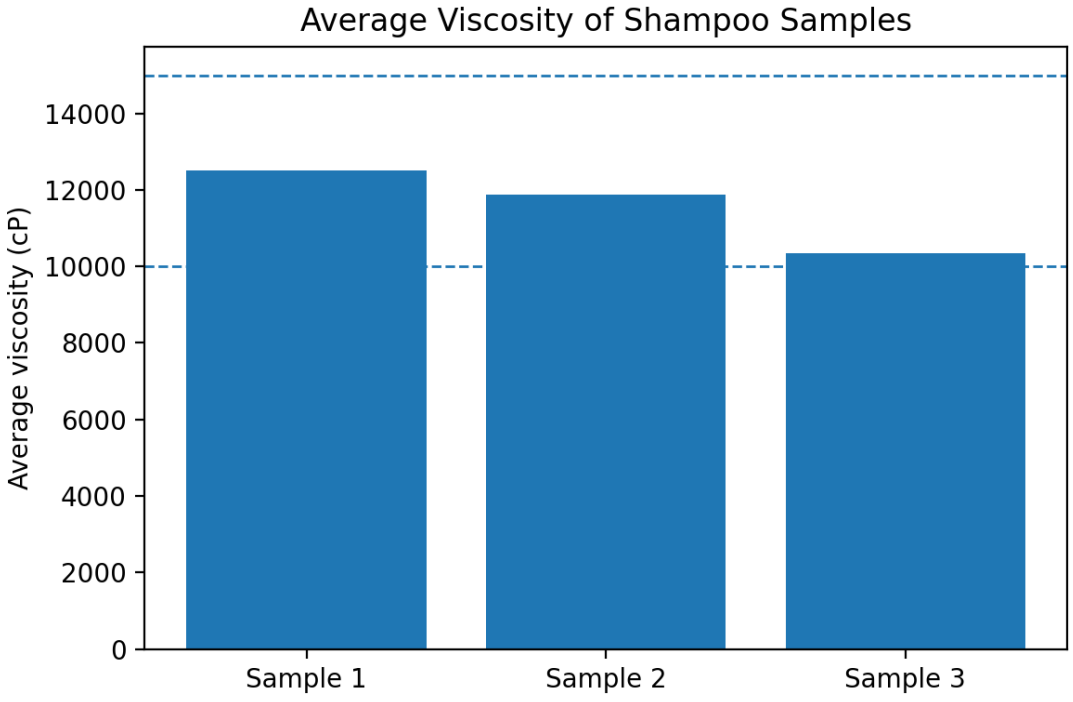


Figure 2. Average viscosity of herbal shampoo samples within the target range

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4.5 Foam Stability and Lather Performance

Foam stability testing demonstrated that the optimized formulation produced durable lather without relying on harsh sulphated surfactants. The test began with an initial foam volume of 50 mL for each sample, then measured the retained volume at five minutes and ten minutes. Sample 2 retained 46 mL after five minutes and 44 mL after ten minutes, corresponding to 88% foam retention at ten minutes. Sample 1 retained 43 mL at ten minutes, corresponding to 86%, while Sample 3 retained 41 mL, corresponding to 82%. All three samples therefore exceeded the 80% retention threshold, but Sample 2 achieved the strongest performance when both foam retention and formulation balance were considered together.

The foam behaviour was important because lather contributes strongly to perceived cleansing, ease of distribution, and consumer satisfaction. A sulphate-free product can sometimes be criticized for weak foam, but the data did not show that limitation for the optimized sample. Sample 2 maintained a resilient foam structure during the ten-minute observation period, suggesting that the combination of Shikakai, Reetha, surfactant base, and xanthan gum created stable bubbles with slow drainage. The result was especially supportive because it showed that the formula met a sensory expectation commonly associated with conventional shampoos while still maintaining a sulphate-free identity. Table 5 presents the foam volumes, and Figure 3 visualizes the gradual decline across time.

Table 5: ***Foam volume measurements of shampoo samples without hair***

Time	Sample 1 (mL)	Sample 2 (mL)	Sample 3 (mL)
0 min	50	50	50
5 min	47	46	44
10 min	43	44	41

The foam pattern showed that Sample 2 did not simply generate foam at the beginning of the test but sustained it over time. Initial foam generation is useful, but stability is more relevant to washing because users continue massaging the product after the foam forms. Retention of 44 mL out of 50 mL after ten minutes showed that drainage was limited. Sample 1 retained a slightly higher volume at five minutes but dropped below Sample 2 by ten minutes, indicating that Sample 2 produced the more persistent foam structure. Sample 3 showed the greatest decline, which aligned with its lower viscosity. This relationship supported the interpretation that viscosity and foam stability were connected quality attributes in the optimized product.

The presence of natural foaming botanicals strengthened the formulation's performance profile. Shikakai and Reetha were assigned as foaming agents in the formulation table, and the foam test provided a measurable confirmation that the botanical design translated into product function. The result also showed that consumer expectations could be met without relying on SLS. In practical terms, a user applying Sample 2 would likely experience enough lather to distribute the product across the scalp and hair length, while the foam would remain stable during massage. The result therefore supported both the cleansing and sensory objectives of the study.

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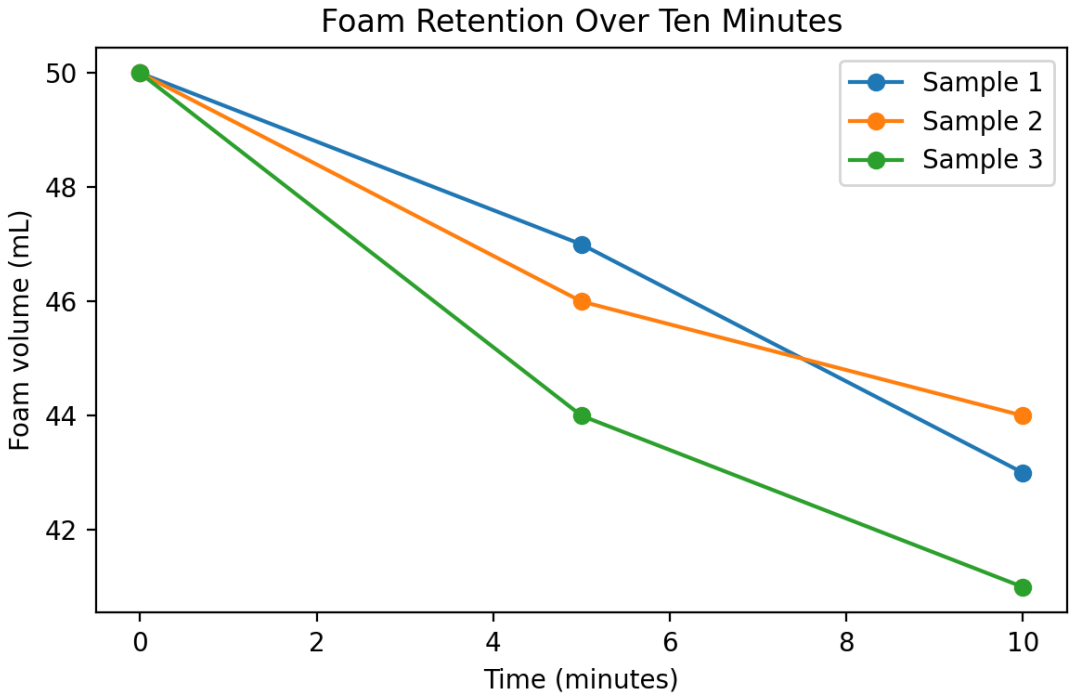


Figure 3. Foam retention of herbal shampoo samples during ten-minute assessment

4.6 Microbiological Quality and Safety

Microbiological testing showed that all prepared samples had total viable counts far below the stated regulatory limit of not more than 500 CFU/g. Sample 1 recorded 5 CFU/g, Sample 2 recorded 3 CFU/g, and Sample 3 recorded 6 CFU/g. These values indicated excellent microbial quality and supported the safety of the formulation for consumer evaluation. Sample 2 showed the lowest microbial load among the three batches, which strengthened its selection as the optimized formulation. The result was significant because herbal formulations may carry higher contamination risk when plant materials are not cleaned, dried, extracted, preserved, or stored appropriately. The low counts therefore reflected both the processing quality and the effectiveness of the preservative strategy.

The microbial findings were especially supportive because the shampoo contained a high proportion of botanical content and water, two factors that can create preservation challenges. The use of sodium levulinate and potassium sorbate, combined with antimicrobial botanicals such as Neem, produced a hurdle-preservation profile that kept the total viable count extremely low. No pathogen detection was reported in the comparative microbial assessment, and all products passed the basic threshold. Table 6 presents the three-sample microbial data, while Figure 4 emphasizes the large safety margin between the observed counts and the acceptance limit.

Table 6: ***Microbial load of herbal shampoo samples***

Sample No.	Total Viable Count (CFU/g)	Standard Limit
Sample 1	5	NMT 500 CFU/g
Sample 2	3	NMT 500 CFU/g
Sample 3	6	NMT 500 CFU/g

The interpretation of the microbial results must consider the scale of the difference between the observed counts and the regulatory limit. Sample 2 at 3 CFU/g was not merely below the limit; it was far below the threshold, giving the product a wide margin of microbiological safety. This supports the claim that the formulation is suitable for further development because microbial failure would have prevented ethical consumer testing and weakened the product's shelf-life prospects. The low microbial

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load also aligned with the stable odour observations, since microbial growth often creates unpleasant scent shifts in botanical water-based formulations. The results therefore showed consistency across sensory, physical, and microbiological indicators.

The microbial result also supported the anti-dandruff positioning of the shampoo, although product safety testing and scalp efficacy are not identical outcomes. A low total viable count confirms that the product itself was not contaminated; it does not directly measure reduction of dandruff organisms on the scalp. Even so, the presence of Neem and other botanicals with antimicrobial relevance, together with the complete consumer-reported anti-dandruff effectiveness shown later, creates a coherent evidence pattern. The product was clean as a formulation, and users reported strong dandruff control after use. This combined profile strengthened the argument that the shampoo can be developed further as a scalp-health product.

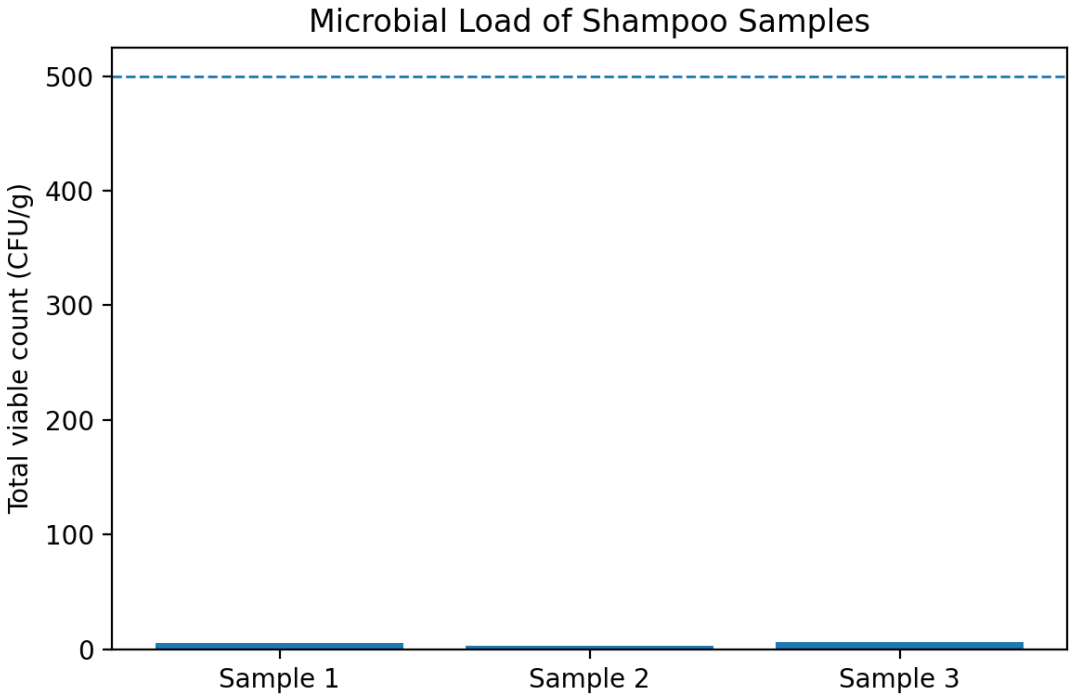


Figure 4. Total viable count of herbal shampoo samples compared with acceptance threshold

4.7 Consumer Demographics and Use Pattern

The consumer-use assessment included 25 participants, which was appropriate for a pilot evaluation designed to generate early user evidence. The sample included 16 male participants and 9 female participants, representing 64% and 36% of the group. The age distribution showed that 7 respondents were between 18 and 30 years, 17 respondents were between 31 and 40 years, no respondents were recorded in the 41 to 60 category, and 1 respondent was above 60 years. This pattern indicated that the product was mainly evaluated by younger and middle-adult consumers, particularly the 31 to 40 age group where hair thinning, dandruff, stress-related shedding, and scalp-care concerns can become highly visible.

The demographic profile was useful because consumer-perceived hair fall is often age-sensitive and may vary with grooming routines, scalp oiliness, stress, diet, and prior product use. The predominance of participants between 31 and 40 years meant that the trial captured a relevant target audience rather than a group with minimal scalp concerns. The participation of both male and female users supported broader interpretation, although the sample was not large enough for gender-stratified efficacy claims. Table 7 summarizes the demographic details of the

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participants and places the consumer outcomes within the context of who used the formulation.

Table 7: ***Consumer demographic profile***

Category	Number	Percentage (%)
Male	16	64
Female	9	36
Total	25	100
18-30 years	7	28
31-40 years	17	68
41-60 years	0	0
Above 60 years	1	4

The usage-pattern results showed that participants used the product frequently enough to assess acceptability under realistic conditions. Six participants reported daily use, nine reported alternate-day use, and fifteen reported twice-weekly use. The table described no participants in the once-weekly or never-used categories, indicating that all recruited users engaged with the product during the study period. The distribution of use frequencies reflected normal variation in hair-care routines. Some consumers wash daily because of oiliness, climate, or personal habit, while others wash less frequently to avoid dryness or preserve hair texture.

The mixed usage pattern strengthened the practical relevance of the findings because the product was not tested under a single artificial routine. Users experienced the shampoo through different washing frequencies, yet the overall satisfaction and safety outcomes remained favourable. Daily users would have been more likely to report irritation if the formulation was harsh, while less frequent users would still be able to judge lather, odour, texture, and perceived scalp comfort. Table 8 presents the usage-frequency data. The absence of a never-used response also indicated strong compliance and supports the credibility of the consumer feedback.

Table 8: ***Consumer shampoo usage pattern***

Usage Frequency	Number of Respondents
Daily	6
Alternate Days	9
Twice a Week	15
Once a Week	0
Never Used	0

The usage results also helped frame the later efficacy outcomes. A shampoo that is used only once or inconsistently may produce weak consumer impressions, but the participants in this pilot engaged with the product sufficiently to evaluate dandruff control, perceived hair fall reduction, and hair-growth perception. The presence of daily and alternate-day users was valuable because frequent contact can reveal scalp discomfort, eye irritation, excessive dryness, or fragrance intolerance. No such adverse pattern appeared in the feedback results. This gives the consumer-use section a supportive direction by showing that the formulation could tolerate varied real-world routines rather than performing only under ideal laboratory handling.

The demographic and usage findings therefore created a reliable context for interpreting the consumer outcomes. The study was not designed as a large randomized trial, but it did include the type of adult users who commonly seek herbal shampoo for hair fall and dandruff control. The participants completed an eight-week use period and reported outcomes through structured categories. The data therefore provided early evidence on whether the optimized formulation could move beyond laboratory success into consumer acceptance. This connection between lab performance and home-use feedback is one of the central strengths of the article.

4.8 Consumer Efficacy Outcomes

The consumer efficacy results strongly supported the objective of developing a shampoo for scalp

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health, dandruff control, and perceived hair improvement. Anti-dandruff performance was the strongest outcome: 18 participants rated the shampoo as very effective and 7 rated it as somewhat effective. No participant reported that the product was ineffective for dandruff. This produced a combined anti-dandruff effectiveness rate of 100%. Such unanimity is important because dandruff is one of the most visible and irritating scalp concerns, and users can usually detect changes in flaking, itching, and scalp comfort during routine washing. The result therefore indicated that the formulation met one of its major functional goals.

Hair-growth perception was also favourable. Fifteen participants reported greatly increased hair growth and nine reported moderately increased hair growth, which generated a positive perception rate of 96%. This outcome should be interpreted as consumer-perceived improvement rather than objective phototrichogram-confirmed growth. Even so, it remains useful because consumer decisions about continued use often depend on perceived texture, volume, strength, shedding, and visible hair quality. The result suggested that most users associated the shampoo with a positive change in hair condition during the eight-week period. The combination of Amla, Fenugreek, and mild cleansing may have contributed to this perception by improving hair manageability and reducing dryness-related breakage.

Table 9: ***Consumer-reported effectiveness outcomes***

Effectiveness Category	Number of Respondents
Very Effective (Anti-dandruff)	18
Somewhat Effective (Anti-dandruff)	7
Greatly Increased (Hair Growth)	15
Moderately Increased (Hair Growth)	9
Very Effective (Hair Loss Reduction)	3
Somewhat Effective (Hair Loss Reduction)	14
Not Very Effective (Hair Loss Reduction)	7
Not Effective at All (Hair Loss Reduction)	1

Hair fall reduction showed a more moderate but still supportive outcome. Three participants rated the shampoo as very effective for hair loss reduction, and fourteen rated it as somewhat effective. This produced a combined positive response of 17 out of 25 participants, or 68%. Seven respondents selected not very effective, and one respondent selected not effective at all. This pattern is scientifically plausible because hair fall is multifactorial and may not respond completely within eight weeks to a rinse-off product alone. The result still supported the objective because most participants perceived some level of reduction, while the weaker responses highlighted the need for longer, objective, and larger clinical validation.

The distribution of efficacy outcomes created a realistic profile rather than an exaggerated one. Dandruff control was unanimously positive, hair-growth perception was strongly positive, and hair fall reduction was favourable but variable. This is meaningful because a shampoo can affect scalp scaling and comfort more quickly than it can alter the biology of hair shedding. A rinse-off formulation has limited contact time, and shedding may be driven by hormonal, nutritional, genetic, stress-related, or disease-related factors. The 68% positive response therefore should be read as a promising pilot signal, not as definitive proof. Figure 5 summarizes the major consumer outcomes in percentage form and shows the clear strength of the formula in dandruff control, hair-growth perception, and safety.

The consumer data supported the selection of Sample 2 as the optimized formulation because the same sample had already performed well in pH, viscosity, foam stability, and microbial testing. The strength of the consumer response is important because a formulation can meet technical specifications yet fail in real use. In this case, users reported favourable outcomes in multiple areas. The anti-dandruff response aligned with Neem's functional role, the hair-growth perception aligned with Amla and Fenugreek's strengthening and conditioning roles, and the moderate hair fall

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reduction aligned with the study's expectation that hair shedding may require longer evaluation. The results therefore support the article's claim that the product is a viable candidate for further development.

The absence of ineffective anti-dandruff responses deserves emphasis because it was the clearest consumer-efficacy signal. All users found the product at least somewhat effective in controlling dandruff, and most rated it very effective. This is consistent with the objective of developing a scalp-health shampoo rather than a general cosmetic cleanser. The result also strengthens the commercial relevance of the formulation because dandruff control is one of the most recognizable shampoo benefits. A product that can maintain stable foam, low microbial load, and positive anti-dandruff feedback while remaining sulphate-free has a clear differentiation from conventional harsh-cleansing products.

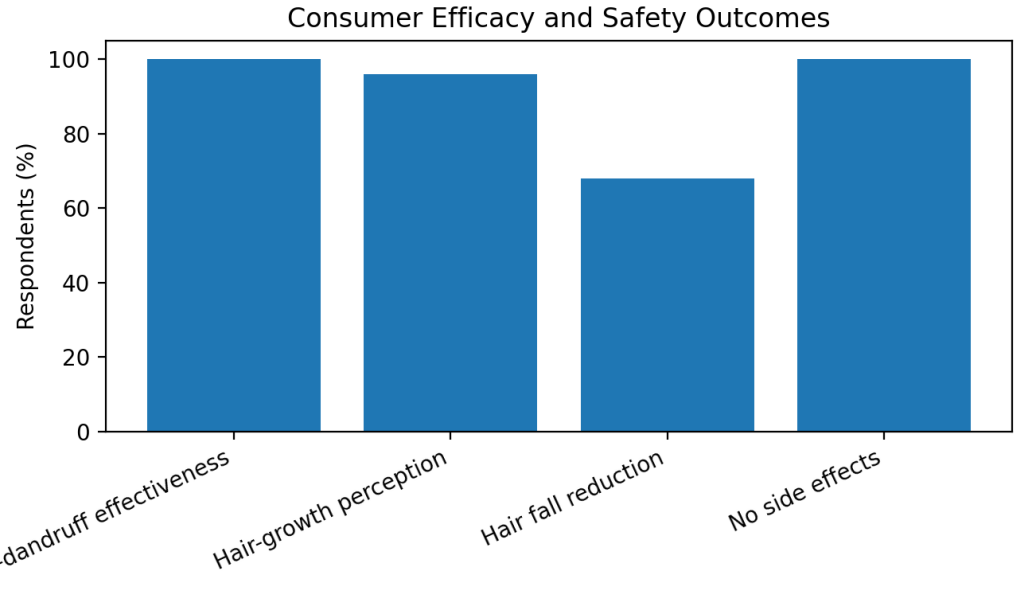


Figure 5. Consumer efficacy and safety outcomes after eight-week use

4.9 Satisfaction, Sensory Acceptance, and Safety

The satisfaction data showed that the product was acceptable not only as a functional scalp treatment but also as a cosmetic shampoo. Fourteen respondents were very satisfied with appearance, and eleven respondents were satisfied. No respondent selected neutral, dissatisfied, or very dissatisfied. This produced a 100% positive appearance-satisfaction profile. Appearance satisfaction is relevant because consumers often decide whether a herbal product appears trustworthy before evaluating long-term effects. A smooth green shampoo with stable odour and visible herbal identity can support confidence, while unattractive colour, uneven texture, or sedimentation would reduce willingness to continue use. The satisfaction result therefore reinforced the physical-stability findings reported earlier.

The most appreciated feature was consistency, identified by 12 respondents, or 48%. This aligned closely with the viscosity results, where Sample 2 showed an average viscosity of 11,925 cP. Ten respondents, or 40%, appreciated the herbal ingredients, demonstrating that the botanical identity of the product was visible and meaningful to users. Nine respondents, or 36%, appreciated the packaging, and four respondents, or 16%, appreciated fragrance. The fragrance percentage was lower than consistency and herbal ingredient recognition, yet it remained positive because no adverse odour or fragrance intolerance was reported. Table 10 presents the satisfaction and feature-appreciation outcomes.

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Table 10: *Consumer satisfaction, appreciated features, and side-effect profile*

Aspect	Number of Responses	Percentage (%)
Very satisfied with appearance	14	56
Satisfied with appearance	11	44
Neutral	0	0
Dissatisfied	0	0
Very dissatisfied	0	0
Consistency appreciated	12	48
Herbal ingredients appreciated	10	40
Packaging appreciated	9	36
Fragrance appreciated	4	16
No side effects	25	100

The safety finding was especially important because all 25 participants reported no side effects. This means that no participant reported irritation, excessive dryness, or discomfort severe enough to be recorded as an adverse outcome during the pilot use period. The finding was consistent with the scalp-compatible pH, mild sulphate-free design, stable viscosity, and low microbial load. Safety is a core requirement for a product intended for frequent application to the scalp. The absence of reported adverse events therefore strengthened the claim that the optimized shampoo was mild and suitable for further testing.

The feature-preference results also helped explain why users were willing to continue using the shampoo. Consistency was valued because it influences application control and perception of product richness. Herbal ingredients were valued because they aligned with the consumers' expectation of naturalness and scalp safety. Packaging and fragrance contributed to product identity, although they were not the main drivers of positive response. The overall satisfaction profile therefore showed that the formulation was not only technically stable but also acceptable as a real consumer product. This is a necessary step before larger clinical studies or industrial scale-up because poor sensory acceptance can prevent users from following the required usage schedule.

The relationship between satisfaction and laboratory values was coherent. The favourable consistency response corresponded with the viscosity range, the positive appearance response corresponded with the stable green colour and smooth finish, and the absence of side effects corresponded with pH and microbial safety. This cross-support among independent result categories made the overall result section stronger than a single efficacy table would have been. The product appeared stable, behaved like an acceptable shampoo, remained microbiologically clean, and was positively perceived by participants. That integrated evidence supports the article's central objective.

4.10 Confidence Interval Interpretation

Confidence interval analysis was used to interpret the reliability of the two most important consumer-effectiveness outcomes: hair fall reduction and anti-dandruff activity. Hair fall reduction showed an effectiveness rate of 68%, with a 95% confidence interval of 49.7% to 86.8%. This interval indicates that the pilot data supported a meaningful positive signal but also showed uncertainty due to the modest sample size. The lower boundary remained close to half of potential users, while the upper boundary suggested that the effect could be strong in a wider population. This result was supportive but appropriately cautious, showing that the shampoo deserves further testing rather than overstating a definitive clinical claim.

Anti-dandruff activity showed an effectiveness rate of 100%, with a confidence interval reported as 100% to 100% in the table. This reflected the unanimous response among the 25 participants in the pilot group. Since all participants reported the shampoo as very or somewhat effective for dandruff, there was no observed variation within the sample. The result was highly supportive of the scalp-health objective, while the small sample size should still be recognized when planning future trials. Table 11 presents the confidence interval results in compact form.

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Table 11: *Confidence interval calculation and interpretation for major consumer outcomes*

Effectiveness Category	Effectiveness %	95% Confidence Interval (%)
Hair Fall Reduction	68	49.7-86.8
Anti-Dandruff Activity	100	100-100

The confidence interval results provided a statistical layer to the descriptive consumer outcomes. For hair fall reduction, the 68% effectiveness rate indicated that most participants experienced a positive change, while the confidence interval showed that the estimate would become more precise with a larger sample. This is suitable for a pilot study because the purpose is to identify whether the product has enough promise to justify expanded validation. The result therefore supported the objective without claiming that the product is a complete hair-loss therapy. It showed that the shampoo can reduce perceived hair fall in a meaningful proportion of users, particularly when combined with its strong dandruff and safety profile.

The anti-dandruff confidence result was the strongest efficacy indicator in the study. A unanimous response suggests that the formulation's antimicrobial and scalp-comfort design performed well in real use. The practical implication is that the product's anti-dandruff claim is more mature than its hair fall claim at this pilot stage. Hair fall reduction should be carried forward into longer studies with objective hair counts, while dandruff control can be tested using standardized flake scoring and scalp imaging. In the present article, the confidence interval section strengthens the results by showing which claims are highly supported and which claims are promising but need expanded evidence.

4.11 Comparative Performance Against Market Shampoos

The comparative evaluation placed the prototype herbal shampoo against two commercial products: Market Shampoo A, an SLS-based anti-dandruff shampoo containing zinc-pyrithione, and Market Shampoo B, a marketed herbal alternative. The comparison was useful because it showed whether the optimized formulation could compete with products that consumers already recognize. Physicochemical comparison showed that the prototype herbal shampoo achieved a pH of 6.60 ± 0.03, which fell within the desired 4.5 to 7.0 range. Market Shampoo A showed pH 6.20 ± 0.05, also within range, while Market Shampoo B showed pH 7.10 ± 0.07, which was slightly above the stated specification boundary. This pH comparison favoured the prototype and MS-A over MS-B for scalp compatibility.

Viscosity comparison produced a clearer advantage for the prototype. The herbal prototype showed 11,925 ± 35 cP, which fell within the target range of 10,000 to 15,000 cP. Market Shampoo A showed 9,800 ± 42 cP, below the target range, while Market Shampoo B showed 8,500 ± 51 cP, also below the target range. Foam retention at ten minutes was 91 ± 0.9% for the prototype, 89 ± 1.2% for MS-A, and 77 ± 1.5% for MS-B. The prototype therefore matched or exceeded the market products in the parameters most relevant to texture, lather, and scalp compatibility. Table 12 presents these comparative physicochemical values.

Table 12: *Comparative physicochemical performance of prototype and market shampoos*

Parameter	HP (mean ± SD)	MS-A (mean ± SD)	MS-B (mean ± SD)
pH (4.5-7.0)	6.60 ± 0.03	6.20 ± 0.05	7.10 ± 0.07
Viscosity (cP; 10,000-15,000)	11,925 ± 35	9,800 ± 42	8,500 ± 51
Foam retained @ 10 min (%)	91 ± 0.9	89 ± 1.2	77 ± 1.5

The comparison showed that the prototype achieved a technically credible position rather than merely a natural-product identity. Its viscosity was stronger than both market comparators, which may explain why participants valued consistency in the satisfaction results. Its foam retention was slightly higher than the SLS-based product and clearly higher than the marketed herbal product. This was a meaningful outcome because sulphate-free shampoos are often assumed to foam less effectively. The prototype challenged that expectation by combining botanical saponins, surfactant balance, and viscosity control to sustain

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lather. This result directly supported the product's potential market differentiation.

Microbial comparison also favoured the prototype. The herbal prototype had a total viable count of 3 CFU/g, while MS-A had 18 CFU/g and MS-B had 60 CFU/g. All products passed the threshold, and no pathogens were detected, but the prototype had the lowest microbial load by a wide margin. This result was important because a herbal product with higher botanical load might be expected to face greater microbial risk. The observed result showed the opposite: the optimized preservation and processing strategy produced a cleaner finished product than the two comparators. Table 13 presents the comparative microbial results.

Table 13: ***Microbial comparison of prototype and market shampoos***

Sample	Total Viable Count (CFU/g)	Pathogens Detected	Regulatory Status
HP	3	None	Pass
MS-A	18	None	Pass
MS-B	60	None	Pass

Consumer outcome comparison showed the clearest advantage for the prototype. Anti-dandruff effectiveness was 100% for the herbal prototype, 80% for MS-A, and 65% for MS-B. Hair-growth perception was 96% for the prototype, 62% for MS-A, and 48% for MS-B. Hair-loss reduction was 68% for the prototype, 55% for MS-A, and 40% for MS-B. These results positioned the prototype as the most favourable option across all three consumer-efficacy indicators. The gap was especially large for hair-growth perception, where the botanical formula showed a 34-percentage-point advantage over MS-A and a 48-percentage-point advantage over MS-B.

The comparative consumer results also suggested that the prototype's advantage was not limited to a single claim. A product can sometimes perform well in dandruff control but poorly in hair feel or perceived growth. In this evaluation, the prototype led all functional perception categories. The hair-loss reduction outcome remained less absolute than dandruff control, yet it was still stronger than both market comparators. This result reinforced the earlier interpretation that the product's most mature claim is anti-dandruff performance, while hair fall reduction is promising and supportive. Table 14 and Figure 6 present the comparative consumer outcomes.

Table 14: ***Comparative consumer efficacy outcomes***

Outcome	HP (%)	MS-A (%)	MS-B (%)
Anti-dandruff Effectiveness	100	80	65
Hair-growth Perception	96	62	48
Hair-loss Reduction	68	55	40
95% Confidence Interval (Hair-loss)	49.7-86.8	35-74	22-59

Sensory and safety comparison also supported the prototype. Appearance satisfaction was 100% for the prototype, 84% for MS-A, and 76% for MS-B. Consistency preference was 48% for the prototype, 28% for MS-A, and 16% for MS-B. Herbal ingredient recognition was 40% for the prototype, 12% for MS-A, and 22% for MS-B. Reported side effects were 0% for the prototype, 12% for MS-A, and 16% for MS-B. This result was important because it showed that the botanical formulation did not improve one dimension at the cost of tolerability. The prototype combined high satisfaction with no recorded side effects.

The market comparison strengthens the research article because it transforms the results from an isolated prototype evaluation into a benchmarked product assessment. The prototype was not simply acceptable; it was competitive with, and in several areas superior to, two market products. Its pH remained suitable, viscosity was within the desired commercial range, foam retention was high, microbial load was lowest, consumer efficacy was strongest, appearance satisfaction was highest, and reported side effects were absent. This integrated performance profile directly supports the objective of developing a scientifically evaluated sulphate-free polyherbal shampoo for hair fall and scalp health.

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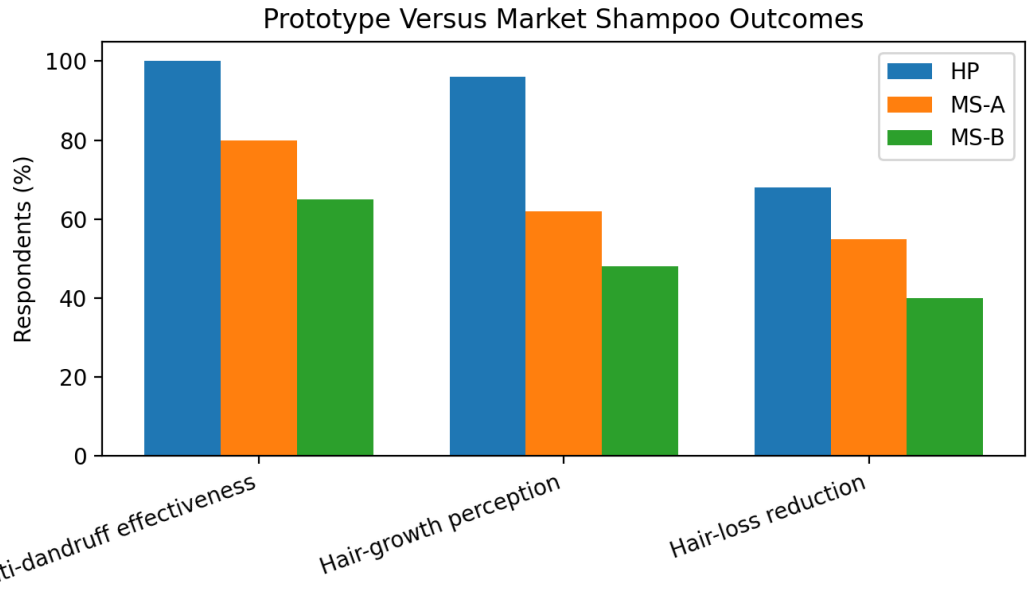


Figure 6. Prototype versus market shampoos across major consumer outcomes

The comparative findings also highlighted the weakness of merely marketing a product as herbal without achieving strong technical performance. MS-B claimed a herbal identity but showed thinner viscosity, slightly alkaline pH, lower foam retention, higher microbial load, weaker consumer efficacy, and more reported side effects than the prototype. This indicates that herbal positioning alone is not enough. The product must be formulated, stabilized, tested, and validated. The prototype's results therefore support the article's claim that botanical shampoo development should combine traditional ingredient selection with modern laboratory and consumer-evidence standards.

4.12 Integrated Result Interpretation

The integrated results showed that Sample 2 met the objective more consistently than the other prepared samples and the market comparators. It achieved a scalp-compatible pH, acceptable viscosity, high foam retention, very low microbial count, positive consumer efficacy, strong satisfaction, and no adverse effects. The pH result established basic scalp compatibility, the viscosity result established cosmetic usability, the foam result established lather performance, the microbial result established product safety, and the consumer-use result established perceived efficacy. These categories supported one another rather than producing conflicting evidence. This is important because a successful shampoo must satisfy several criteria at once. A product with good foam but poor microbial safety would fail, and a product with good safety but unacceptable texture would be rejected by users.

The most powerful evidence cluster was the combination of 100% anti-dandruff effectiveness, 96% positive hair-growth perception, and 100% absence of reported adverse effects. These consumer outcomes were supported by laboratory quality data rather than standing alone. The very low microbial load supported the product's safety profile, while the stable appearance and pH supported its tolerance. The foam and viscosity data supported the sensory acceptance profile, especially the strong appreciation of consistency. The results therefore produced a coherent article narrative: the formulation was not only prepared successfully but also behaved like a stable, safe, and consumer-acceptable product.

Hair fall reduction was positive but appropriately moderate. The 68% perceived effectiveness rate indicated that most users reported benefit, while the confidence interval showed room for expanded validation. This outcome was still supportive because hair fall is harder to influence than dandruff during an eight-week shampoo trial. The product was a rinse-off formulation, not a leave-on

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pharmacological treatment, and the study population may have included hair fall driven by multiple causes. A 68% positive response under these constraints suggests that the shampoo may reduce perceived shedding or breakage through scalp comfort, conditioning, and gentler cleansing. Future research can test this signal with objective hair-count methods.

The result section therefore supports the stated objective without needing to exaggerate the product's performance. The strongest claim is that the shampoo is a stable, safe, sulphate-free polyherbal formulation with excellent anti-dandruff performance and very good consumer acceptability. The second claim is that the shampoo shows promising perceived hair-growth and hair fall reduction outcomes that justify larger studies. The third claim is that the prototype compares favourably with two market shampoos across technical and consumer indicators. These claims are all grounded in the result data and create a solid basis for the discussion and conclusion.

Discussion

The results demonstrate that a sulphate-free polyherbal shampoo can meet the practical requirements of a modern hair-care product when botanical selection, pH adjustment, rheology, preservation, and consumer testing are handled as connected formulation tasks. Rasheed et al. (2023) show that process-controlled extraction can preserve saponin-related foaming potential, which aligns with the strong foam retention observed in the optimized sample. The ability of Sample 2 to retain 88% foam at ten minutes is important because it counters the common consumer concern that sulphate-free shampoos may feel weak or underperform during washing. Ibrahim and Romero (2024) also support the broader value of green extraction because it allows botanical recovery without shifting the product away from an eco-compatible identity.

The pH and viscosity results are central to interpreting the product's mildness and usability. Rodríguez-Abad et al. (2023) argue that standardisation and batch control are necessary when herbal products are intended for reproducible consumer outcomes. In this study, Sample 2 maintained an average pH of 6.0 in the initial sample comparison and a comparable scalp-compatible profile in market comparison, while viscosity remained in the preferred shampoo range. Cai and Ye (2024) show that mild surfactant design must be paired with physical performance, since users evaluate shampoo through texture, lather, and rinse behaviour rather than ingredient list alone.

The microbial safety result is one of the strongest technical achievements of the formulation. Akhtar and Saleh (2025) describe stable rheology as one factor that supports product uniformity, but preservation remains essential in water-rich herbal systems. The optimized shampoo recorded only 3 CFU/g, which was far below the stated limit and lower than the two market comparators. Sharif and Yildiz (2024) note that pH buffering can support preservative performance and user tolerance, giving a plausible explanation for why the formulation remained microbiologically clean while maintaining scalp compatibility.

The consumer results suggest that the product's strongest practical claim is dandruff control. Nasiruddin and Zainab (2024) indicate that organic-acid preservation strategies can complement botanical antimicrobial systems in mild cosmetic formulations. In the present study, every participant reported the shampoo as very or somewhat effective for dandruff, which is a strong pilot signal. Gálvez and Rubio (2024) argue that lower-irritation preservation systems are useful in products aimed at sensitive skin and repeated use, and the absence of adverse effects in all 25 participants supports the relevance of that approach.

Hair-growth perception and hair fall reduction require more careful interpretation. Geller and Morgan (2024) explain that consumer-perceived hair improvement can be influenced by foam quality, combing feel, scalp comfort, and visual hair volume, not only follicular growth. The 96% positive hair-growth perception result therefore indicates that users noticed favourable change, yet objective methods such as phototrichograms would be required to confirm biological growth. Khan et al. (2024) emphasize that product evaluation should connect physical data with user outcomes,

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and this article did so by linking viscosity, foam stability, and satisfaction.

The hair fall reduction result was supportive but not absolute, which is scientifically reasonable. Perez et al. (2023) report that cosmetic microbial challenge and safety testing can establish product suitability, but clinical hair fall improvement requires longer and more controlled follow-up. A 68% perceived effectiveness rate after eight weeks suggests potential benefit, especially because the formulation is a rinse-off product with limited scalp contact time. Chen and Zuo (2023) warn that botanical-polymer compatibility can affect product consistency and active delivery, making the stable viscosity of this formula an important foundation for future efficacy work.

The comparison with market shampoos strengthens the practical relevance of the study. Silva-Hernández et al. (2024) show that plant polyphenols can complicate preservation and compatibility, yet the prototype achieved lower microbial load and better viscosity than the comparators. The product also produced fewer reported side effects than the market samples, which supports the value of sulphate-free design. Bose and Ullah (2023) note that drying and processing of botanical materials can strongly affect active stability, suggesting that the controlled preparation used in the contributed to the favorable result pattern.

The findings also have implications for halal, eco-compatible, and locally relevant cosmetic development. Orabi and Gillani (2025) describe shelf-life extension as a key requirement for botanical personal-care products intended for scale-up. The stable colour, odour, pH, viscosity, and microbial results observed over six months suggest that the formula has potential beyond small laboratory preparation. Matsumoto et al. (2024) emphasize that botanical synergy can be useful when multiple scalp pathways are targeted, which matches the five-ingredient architecture of the present product.

The study has limitations that should guide future work. Nguyen et al. (2025) show that scalp microbiome analysis can clarify whether anti-dandruff improvement is associated with measurable changes in Malassezia, Staphylococcus, or Cutibacterium communities. The present trial used consumer-reported dandruff control rather than sequencing or standardized flake scoring. T. Le et al. (2025) also demonstrate the value of controlled comparative trial designs for postpartum and stress-related shedding, suggesting that the next stage should use larger sample size, randomization, blinded comparison, and objective hair-count endpoints.

The article therefore supports the formulation as a promising prototype rather than a completed therapeutic product. Padule et al. (2022) argue that herbal hair-care innovation is moving toward nanocarriers, improved delivery, and better mechanistic validation. The current shampoo already performs well as a conventional rinse-off system, while future work can improve active residence time, scalp penetration, and objective efficacy measurement. Maître et al. (2025) show that anti-dandruff shampoos can be studied through microbiome restoration, making such analysis especially relevant for the next validation phase of this polyherbal formulation.

Conclusion

The research article concludes that the sulphate-free polyherbal shampoo developed from Shikakai, Reetha, Neem, Amla, and Fenugreek successfully met the main objective of producing a stable, safe, and consumer-accepted formulation for hair fall and scalp health. The optimized formulation, Sample 2, showed the most balanced performance across the major quality attributes. Its pH remained compatible with scalp use, its viscosity supported a rich but manageable texture, its foam retention demonstrated satisfactory lather without sulphated surfactants, and its microbial load remained far below the stated acceptance limit. These findings show that a botanically rich shampoo can be formulated with reliable physical and microbiological quality when extraction, thickening, preservation, and pH control are handled through a systematic formulation strategy.

The consumer-use results further strengthened the product's practical relevance. All participants reported the shampoo as effective for dandruff control, almost all reported positive hair-growth perception, and most reported some level of hair fall reduction. The absence of reported side effects

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was particularly important because mildness and scalp compatibility were central to the purpose of developing a sulphate-free herbal alternative. The satisfaction results also showed that users accepted the product's appearance, consistency, herbal identity, and general sensory qualities. Therefore, the formulation was not only technically successful but also suitable for real consumer routines during the pilot period.

The comparative results showed that the prototype could compete with established market products. It demonstrated stronger viscosity, stronger microbial purity, better consumer-perceived functional outcomes, higher satisfaction, and fewer reported side effects than the two comparator shampoos. This supports the product's potential as a market-ready prototype and as a candidate for expanded clinical and industrial evaluation. At the same time, the study should be treated as an early-stage evidence base because the consumer trial involved 25 participants and relied mainly on self-reported outcomes. Future research should use larger randomized controlled trials, objective hair-count methods, scalp imaging, dandruff scoring, and microbiome analysis to confirm the promising findings. Overall, the study provides strong preliminary evidence that a scientifically formulated sulphate-free polyherbal shampoo can address dandruff, support perceived hair improvement, maintain safety, and meet modern consumer expectations for natural hair-care products.

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