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Research Paper

Comparative Evaluation of Surfactant Activity of Sapindus Mukorossi Gaerth, Trigonella Foenum-Graecum L And Glycyrrhiza Glabra Linn in Herbal Shampoo

Shubham Chavan*, Mohini Mishra, Tarun Mishra, Vaishali Kundalia, Sagar Choudhary

Department of Pharmacy, VIVA Institute of Pharmacy, Mumbai, Maharashtra, India.

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ABSTRACT

Herbal shampoos are gaining popularity as they are considered safer and do not have the harmful side effects that synthetic shampoos can cause. This study was conducted to prepare and compare four different herbal shampoo formulations containing natural surfactants and plant-based ingredients. The formulations used various extracts of Sapindus mukorossi (Aritha), Trigonella foenum-graecum (Methi) and Glycyrrhiza glabra (Liquorice) individually or in combination. The formulations were tested for physical, chemical and performance characteristics including organoleptic properties, pH, viscosity, solid content, surface tension, foaming ability, wetting time and cleansing ability. All formulations were found to be within acceptable range and suitable for the application to the scalp. Of the four test formulations, Aritha produced the most effective results in surface tension reduction, foaming ability, wetting time and cleansing efficiency. The combination of herbs in formulation (Aritha + Methi + Liquorice) produced a more balanced product, demonstrating both effective cleansing and conditioning, along with better compatibility with the scalp based on the synergistic interaction of the multiple herbal extracts. This suggests that there is value in using multiple extracts that possess different functional properties, rather than simply relying on one extract that may provide an individual benefit. Based on the findings from this study, combined herbal extracts offer the possibility of being used as effective substitute(s) for synthetic surfactants in shampoo formulations, thus contributing to the creation of safer and more effective herbal cosmetic products.

INTRODUCTION

The appearance of hair is important to each individual's self-esteem and confidence, while

***Corresponding Author:** Shubham Chavan
Address: *Department of Pharmacy, VIVA Institute of Pharmacy, Mumbai, Maharashtra, India..*
Email ✉: chavanshubham9562@gmail.com
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the health of one's hair and scalp is integral to their personal hygiene. Most people will use a shampoo to cleanse their hair by removing dirt, oil, and other contaminants from the hair and scalp. Although most conventional shampoos use synthetic detergents (surfactants) such as sodium lauryl sulfate or sodium laureth sulfate, which provide good foaming and cleaning ability, they can also have negative effects on the skin and hair, such as causing irritation and dryness of the scalp, denaturation of protein, and damage to the cuticle when used frequently or over long periods of time[1-3]. Because of these negative effects from traditional surfactants, researchers and manufacturers of cosmetics have been researching and developing alternative and safer milder products to replace these harsher ingredients[4]. There continues to be a recent resurgence of interest in herbal cosmetics because of the approximately fewer side effects (when used) and for greater perceived safety (vs) traditional synthetic chemical products[5,6]. Herbal shampoos are typically considered to be cosmetics that were made from extracts of plants or herbs, which contain (active) ingredients that may provide cleansing, conditioning, anti-microbial, and/or nutritional benefits. In contrast to synthetic products, herbal shampoos contain many naturally occurring phytoconstituents (e.g., saponins, flavonoids, mucilage) that contribute to their mild (less abrasive) cleansing ability and also promote the health of the scalp[7]. The preference for eco-friendly and skin-compatible cosmetics has steadily grown amongst consumers[8].One of the more common natural surfactant-based hair-care products is *Sapindus mukorossi*, or Aritha, also known as the soapnut, which belongs to the Sapindaceae family. The pericarp of this fruit possesses a high concentration of saponins that provide a natural foaming, cleansing activity similar to that of synthetic surfactants[9,10]. This is why it has been used traditionally as a natural detergent for washing hair and other textiles[11]. *Trigonella foenum-graecum* or methi, is another popular plant used in natural cosmetic products for hair care. Methi seeds have mucilage, proteins, nicotinic acid, and flavonoids which all help condition hair, strengthen the hair follicles, prevent dandruff and hair loss, and provide a calming effect to the scalp while improving hair texture[12,13].*Glycyrrhiza glabra* (liquorice) is a commonly used herb in hair-care products. The root of the plant contains glycyrrhizin, flavonoids, and numerous phenolic compounds, all of which possess anti-inflammatory, antimicrobial, and antioxidant properties[14,15]. The pharmacological actions of the above constituents make liquorice beneficial for maintaining the health of the scalp and mitigating the discomfort associated with cosmetic hair-care formulations [16-18]. In the present study herbal shampoo was developed by taking individual plants and all plant together in formulation and comparative evaluation was done.

MATERIALS AND METHODS

Materials

Sapindus mukorossi (Aritha) dried pericarps were obtained from an unrefined herbal pharmacy located in Mumbai, India. *Trigonella foenum-graecum* (Methi) seed powder and *Glycyrrhiza glabra(*Liquorice) root powder were also purchased from different vendors. The plant-derived materials were identified using morphological characteristics and pharmacognostic characteristics from the literature. After cleaning *Sapindus mukorossi* of any attachments, it was shade-dried and coarsely reduced to powder via a mechanical grinder; the other two powders were left unaltered. All materials were kept in tightly sealable plastic containers at ambient temperature until needed. The excipients used to formulate the samples included xanthan gum (thickening agent), cetyl alcohol (conditioning agent), methyl paraben

(preservative) and citric acid / sodium hydroxide (pH adjustment). All chemicals and reagents used were of analytical quality, obtained from known vendors. Distilled water was the solvent used to prepare all formulations.

Preparation of Extracts

The powdered plant materials of *Sapindus mukorossi* (Aritha), *Trigonella foenum-graecum* (Methi) and *Glycyrrhiza glabra* (Liquorice) have undergone hydro-alcoholic extraction. Each powdered drug is extracted using an ethanol and water (70:30 v/v) hydro-alcoholic solvent, by using 250mL of solvent for every 25g of powdered drug. The extraction of phytoconstituents was achieved using heat (60-70° C) and stirring continuously for a period of 2-3 hours[19,20]. Extracted material was filtered through two types of filter (muslin cloth, and then Whatman filter paper), in order to remove insoluble material.

Excess solvent was removed from the extract by concentrating it using a water bath at lower than 60 ° C until a semi-solid extract remained. Each of the extracted materials were weighed, and placed in air-tight containers at 4° C, until used in further experiments.

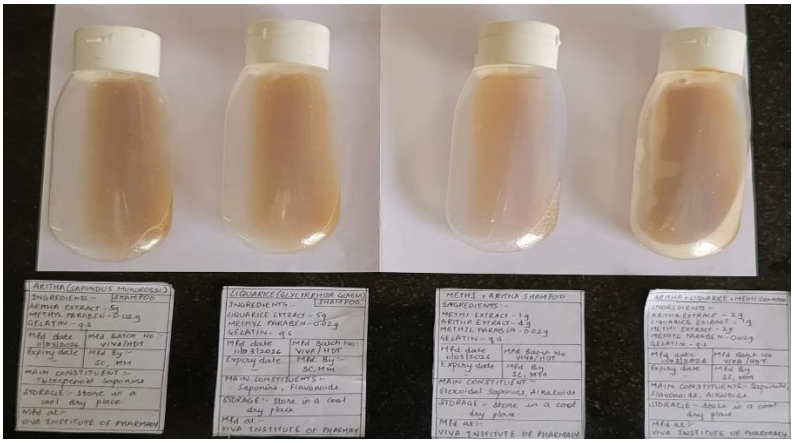
The percentage yield of the extract was calculated using the following formula and was determined to be between 12 and 18% w/w: because of the successful bio-active constituent extraction from the crude drugs.

Formulation of Herbal Shampoo

Four different formulations of herbal shampoo were created using a common base formulation; however, only the extract type was changed. This procedure provided assurance that the physicochemical and performance characteristics of the formulations would differ only as a result of differences in the constituents (derived from the extracted herb) utilized in each formulation. The composition of the formulations is presented in Table 1.

Table 1: Composition of Herbal Shampoo Formulations

Ingredients	F1 (Aritha)	F2 (Liquorice)	F3(Aritha + Methi)	F4(Aritha + Methi + Liquorice)
Aritha extract (g)	10	-	5	2
Methi extract (g)	-	-	5	1
Liquorice extract (g)	-	10	-	2
Xanthan Gum (g)	0.5	0.5	0.5	0.5
Cetyl alcohol (g)	1	1	1	1
Methyl Paraben (g)	0.2	0.2	0.2	0.2
Gelatin	q.s	q.s	q.s	q.s
Distilled water (ml)	q.s to 20	q.s to 20	q.s to 20	q.s to 20



Procedure

The different herbal shampoo formulations were created with the various plant extracts incorporated into a common base (viscous) system. The xanthan gum was first dispersed in distilled water and mixed continuously until a consistent viscous base is attained. The cetyl alcohol was melted separately (i.e., above 60° C) and added gradually into the above base while mixing continuously to give the product its respective conditioning properties.

The required amount of the herbal extract was added into the viscous base with continuous mixing to ensure the uniformity of all the ingredients. Methyl paraben was added as a preservative; and the final pH of all formulations were adjusted in the range of 5-7 with either citric acid or sodium hydroxide solution.

The volume of each of the formulations was finally brought to 20 mL with distilled water and mixed thoroughly to ensure the shampoo, in all formulation batches, was homogeneous. All formulations were prepared with identical processes to provide the uniformity needed to properly evaluate and validate for comparison purposes.

EVALUATION OF HERBAL SHAMPOO FORMULATIONS

The herbal shampoo formulations (F1-F4) were evaluated for various physicochemical and performance properties by using standard assessment procedures.

Organoleptic Characteristics

The organoleptic properties of the formulations (color, clarity, scent and homogeneity) were assessed visually. The assessment was performed against a white background in order to identify any targeted visual imperfections or phase separation[21,22].

pH Measurement

A digital pH meter was used to measure the pH of the formulations at room temperature (25±2° C). 10% (v/v) concentrations of the shampoos were made from distilled water and this concentration was used to measure the pH, which was confirmed to be between 5.0-7.0 for compatibility with the scalp and hair[23].

Viscosity Measurement

The viscosity of the shampoo formulations was measured using an Ostwald viscometer at room temperature (25±2° C) where measurements were taken based upon time to flow through the viscometer and compared with that of distilled water. All measurements were repeated three times resulting in average values being determined[26,28].

Solid Content Determination

The determination of solid content was performed via evaporation. Approximately four grams of the shampoo was accurately weighed and placed in a pre-weighed evaporating dish. The sample then was evaporated on a water bath to a constant weight. The percentage of solid content was calculated using the formula[22,24].

Surface Tension

Surface tension of formulations was measured using the drop count method with a stalagmometer. A 10% w/v shampoo solution was prepared and a number of drops were counted. Surface tension was calculated using the standard formula and was compared to that of distilled water[23,25].

Foaming Ability and Stability

The foaming ability was measured by using a cylinder shake method in which 1% shampoo solutions were shaken vigorously in graduated cylinders. The volume of foam generated was measured immediately after shaking and over intervals of time to give an indication of stability of foam[24,26].

Wetting Time

The wetting time was measured using the canvas disc method. A canvas disc was placed on top of the 1% shampoo solution and the time taken for the disc to sink was recorded as wetting time[25,27].

Dirt Dispersion Test

The cleaning effectiveness was determined by putting a drop of India Ink in a test tube containing shampoo and shaking the test tube. The presence of ink in the foam is to determine the cleaning efficacy (less ink in foam; greater cleaning efficiency)[22,29].

Cleansing Action

Each formulation was evaluated by applying it to a surface that was contaminated with oil/dirt and measuring how well the contamination was removed from the surface. All formulations were evaluated under the same conditions[22,29].

Skin Irritation

A small patch test on the skin has been done to assess the possibility of any skin irritation or allergic response to the formulations. After 24 hours the skin was checked for signs of irritation (redness, itching, or swelling) in the area of the formulation[21,28].

Stability Studies

The stability of the formulations has been tested at three different separate storage environments:

At room temperature (25° C ± 2° C)

At refrigeration temperature (4° C ± 2° C)

At accelerated temperature (40° C ± 2° C, 75% RH ± 5% RH)

Samples were monitored for changes in pH, viscosity, appearance, and phase separation after being stored in these various environments at certain times[22,28].

RESULT AND DISCUSSION

The prepared herbal shampoo formulations (F1−F4) were assessed for a range of physicochemical (such as viscosity, pH) and performance parameters (such as foaming activity, detersive ability) and the results are listed below in the associated tables. The variation between formulations can be attributed to the varying composition and combinations of herbal extracts used to create the formulations.

Organoleptic Properties

All formulations were homogeneous with no visual signs of phase separation; this indicates that the formulations are stable. The colour of the formulations differed from yellowish to dark brown based on the types of herbal extracts added into the formulations. *Sapindus mukorossi*, added

into F1 and F4, provided a dark colour to these formulations because of the presence of saponins; whereas F2 contained a lighter colour than F1 and F4. F3 contained slight turbidity due to the presence of mucilage obtained from *Trigonella foenum-graecum*, which increases the viscosity of a liquid, but decreases its clarity. Compared with the other three formulations, F4 showed the most consistent and uniform appearance, which indicates that the herbal extracts used in F4 were the most compatible and therefore provided a more stable formulation.

Formulation	Colour	Appearance	Homogeneity	Remarks
F1	Dark brown	Smooth	Good	Presence of saponins (*Sapindus mukorossi*)
F2	Light brown	Clear	Good	Lighter due to absence of heavy extracts
F3	Brown	Slightly turbid	Good	Turbidity due to *Trigonella foenum-graecum* mucilage
F4	Dark brown	Smooth & uniform	Excellent	Best consistency and compatibility

pH Determination

All formulations' pH values ranged from 5-7, making them suitable for application to the scalp since this is within the natural acidic pH range of healthy skin.

Formulation	pH(Mean ± SD, n=3)
F1	5.5± 0.1
F2	5.3± 0.1
F3	5.8± 0.2
F4	6.0± 0.1

F1 and F2 had a slightly acidic pH, which will help reduce the chance of irritation on the scalp and help maintain the integrity of the hair cuticle. The slight increase in pH of F3 and F4 may be caused by the higher number of phytoconstituents present, but since they are still in the acceptable range, these formulations are also considered safe for topical use.

Viscosity Measurement

Formulation	Viscosity (cP)
F1	1450± 50
F2	2100± 80
F3	1850± 60
F4	1700± 55

The highest viscosity of formulation F2 because of the phytoconstituents from Glycyrrhiza glabra that contribute to the thickness of the product. F3 and F4 had moderate viscosities, indicating that they have balanced rheological behavior. This viscosity range is necessary for the formulation of shampoos, allowing ease of use and adequate spreading properties for consumer acceptance. In other words, formulations of shampoos should be of a viscosity that allows for easy application without being too viscous or too thin. The viscosity of F1 was lower than other formulations and may be attributed to the fact that surfactants were more dominant than thickeners in this formulation. Low viscosity will improve the ease of application; however, too low of a viscosity can hinder handling properties. F4 had an ideal viscosity for shampoo formulations because it was well-balanced in flow property and use.

Solid Content Determination

Formulation	Solid Content (%)
F1	10.5
F2	3.5
F3	6.8
F4	5.2

The formulation with the highest level of saponins and other extractives from the Sapindus mukorossi (F1) has the highest solids content; therefore, there is the highest viscosity and film-forming attributes, providing the best body and consistency in the shampoo. Conversely, excessive solids may impede rinsing and cause build-up on the hair. The lower solids level offers excellent spreadability and low washing difficulty but may lead to lesser viscosity in the formulation. F3 and F4 had moderate solids content; therefore, a balance between consistency and washability was established. Of all the formulations, F4 had the best overall balance and would suit the needs of using the shampoo daily.

Surface Tension

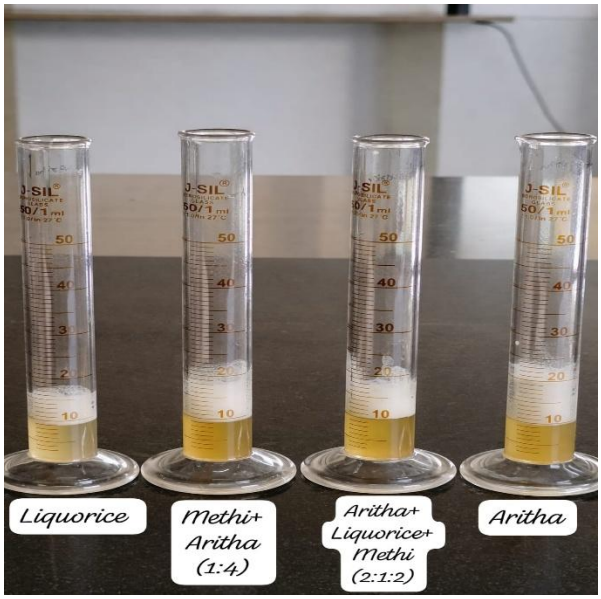
Formulation	Surface Tension (dynes/cm)
F1	31.2
F2	36.8
F3	38.5
F4	35.2

F1 had the lowest surface tensions and is therefore the most efficient in terms of its surfactant action as a result of saponin components in Sapindus mukorossi, which are known to be very good at lowering interfacial tension. F4 showed a lower surface tension as well when compared to F2 and F3 indicating that the combination of herbal extracts also provides a good degree of surfactant-like properties in addition to additional functional properties. In F2 and F3 the surface tensions were much higher than in F1 and F4 thus demonstrating lower surfactant efficiency, this may be due to non-surfactants present such as mucilage and other polar compounds, which do not effectively reduce surface tensions. Surface tensions are an important variable for determining cleansing ability; however other variables such as conditioning effect of the product, mildness of the product and interaction of the herbal ingredients must also be taken into consideration when evaluating overall performance of a shampoo.

Foaming Ability & Stability

Formulation	Foam Height(cm)
F1	6.8
F2	3.5
F3	5.5
F4	4.6

Foaming studies demonstrated that the *Sapindus mukorossi* formulation produced the highest foam volume due to its high saponin content. The addition of *Trigonella foenum-graecum* and *Glycyrrhiza glabra* resulted in a reduction in foam volume, likely due to the presence of mucilage and other phytoconstituents that interfere with foam formation. It is important to note that reduced foam does not necessarily correlate with reduced cleansing efficiency in herbal formulations.



Wetting Time

Formulation	Wetting Time(sec)
F1	3
F2	6
F3	4
F4	5

F1 had the shortest wetting time and therefore had the best surface-active properties. F2 formulation containing *Glycyrrhiza glabra* had the longest wetting time, indicating it had the least surfactant properties. The formulation of *Sapindus mukorossi* with *Trigonella foenum-graecum* had an intermediate wetting time. The combination formulation had a longer wetting time than Aritha alone due to the presence of mucilage or other phytoconstituents. Overall, all formulations had adequate wetting ability for use in shampoos.

Dirt Dispersion Test

Formulation	Dirt in Foam	Dirt in Water	Evaluation
F1	Very low	High	Excellent
F2	Moderate	Moderate	Fair
F3	Low	High	Good
F4	Very low	Very High	Excellent

The formulation of *Sapindus mukorossi* provides very little dirt in foam, which indicates it has cleansing ability. The combination formulation produces excellent dispersion of dirt into the water phase. The formulation of *Glycyrrhiza glabra* exhibited moderate dispersion; however, all of the formulations had acceptable dirt removal characteristics.

Cleansing Action

Formulation	Cleansing Action
F1	Excellent
F2	Moderate
F3	Good
F4	Good

The formulation containing *Sapindus mukorossi* showed excellent cleansing ability. Combination formulations were also effective at cleaning. The formulations containing *Glycyrrhiza glabra* had

moderate cleansing capabilities. Overall all formulations removed dirt and oil effectively.

Skin Irritation

Formulation	Redness	Itching	Irritation	Evaluation
F1	Slight	None	Mild	Acceptable
F2	None	None	None	Excellent
F3	None	None	None	Excellent
F4	None	None	None	Excellent

In certain situations, implementation of the formulation which contained *Sapindus mukorossi* alone resulted in some redness, likely due to the ingredient's strong surfactant properties. There was no irritation seen with the formulation that contained *Glycyrrhiza glabra* because of how it functions as an anti-inflammatory. Overall, in the combination formulation of *Sapindus mukorossi*, *Trigonella foenum-graecum* and Glycyrrhiza glabra, there was no evidence of irritation present, which supports the formulation's mildness and compatibility with skin system; showing that conditioning and soothing ingredients lessen the severity of surfactant action resulting in a formulation suitable for use on a daily basis.

CONCLUSION

The current research successfully produced and assessed four herbal shampoo formulations including different combinations of various natural plant extracts; *Sapindus mukorossi* (Aritha), *Trigonella foenum-graecum* (Methi) and *Glycyrrhiza glabra* (Liquorice). The physicochemical and performance evaluation for these formulations were methodically conducted based upon the following parameters: pH; viscosity; solid content; surface tension; foaming potential; wetting time; and cleaning ability. Each of the aforementioned formulations was confirmed to be within the acceptable limits currently established for cosmetic purposes. As such, these formulations would be considered to potentially qualify as herbal shampoo products. The results above demonstrate a clear distinction between each formulation's constituent extraction and consequently its impact on the overall performance of the resulting herbal shampoo.The formulation to exhibit the maximum degree of performance based upon the aforementioned parameters (i.e., surface tension reduction, foam quantity/quality, wetting properties) from a "purely cleansing" perspective would be F1. Conversely, when evaluating overall performance (including cleaning efficiency, conditioning effect, and formulation composition balance) the effectiveness of formulation F4 clearly surpassed that of formulation F1. In F4, the natural surfactant activity provided by *Sapindus mukorossi*; the conditioning effects attributable to *Trigonella foenum-graecum*; and the scalp compatibility and soothing attributes associated with *Glycyrrhiza glabra* produced a harmoniously balanced physicochemical profile and increased functionality.The results of this research show that while individual extracts are able to enhance the performance of some parameters, the combination of herbal ingredients has the potential to create a more efficacious and multifunctional product. This further suggests that the presence of multiple phytoconstituents could influence certain physical properties of these products (e.g., foaming and surface activity) and would require additional refinement.Overall, this research has concluded that the use of several natural ingredients in the formulation of herbal shampoos provides an effective means of cleansing, conditioning, and being gentle on the scalp, all promoting their ability to serve as a safer and more environmentally friendly alternative to synthetic

products. To better support their use, we would recommend that further research be conducted in the areas of long-term stability, antimicrobial activity, and clinical assessment of these products to continue to enhance their potential.

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