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Colour cosmetics: Extraction and application of plant-based pigments in the shampoo formulation

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Abstract
Hair plays a crucial role in human aesthetics and personal care. The aim of this research is to develop a shampoo using plant-based pigments extracted from Neem leaves, Fenugreek seeds, Hibiscus flowers, and Butterfly Pea flowers. These natural pigments not only provide vibrant, eco-friendly colors but also offer significant scalp benefits, such as promoting hair growth, reducing dandruff, and delivering antioxidant and nutrient-rich properties making them a safer and holistic alternative to synthetic dyes. Two types of shampoo formulations were developed, transparent and opaque shampoo, incorporating plant-based pigments. The physicochemical parameters of these formulations were evaluated as per BIS standards. The shampoos exhibited excellent results, with no phase separation or color degradation, even after stability testing under controlled environmental conditions 25 ± 1 °C and 60 ± 10% RH. The antimicrobial evaluation confirmed that the plant-pigment-based shampoos were free from microbial contamination. Furthermore, FTIR analysis of the pigments from Butterfly Pea, Hibiscus, Neem, and Fenugreek confirmed the presence of key functional groups such as O-H, C=O, C=C, and C-O, which correspond to flavonoids, anthocyanins, terpenoids, and saponins. These bioactive compounds contribute to the shampoo's antioxidant, antimicrobial, conditioning, and foaming properties, reinforcing its potential as an effective natural pigment based cosmetic formulation.

Keywords: Shampoo, plant based pigments, antioxidant, antimicrobial, synthetic dye

1. Introduction
Since ancient times, people have used herbs for cleansing, beautifying, and managing hair, Hair is considered an integral part of human beauty [1]. Shampoos are primarily composed of detergents and surfactants and are classified as cosmetic preparations designed for washing hair and the scalp [2]. In recent years, consumers have become increasingly conscious of scalp health and prefer natural shampoos over conventional synthetic formulations [3].

Many synthetic shampoo ingredients have been reported to cause adverse effects, including scalp irritation, hair loss, and discomfort [4]. Additionally, various antifungal and antimicrobial agents used in shampoos may contribute to unwanted side effects [5]. Synthetic pigments, commonly used for coloration, pose significant health risks due to their potential toxicity and carcinogenicity. As a result, their use has been declining, leading to a growing interest in natural pigments as safer alternatives [16].

Hibiscus rosa-sinensis contains many beneficial components. Antioxidant-rich flavonoids and polyphenols, such as quercetin and anthocyanins, are rich in it [7]. Hibiscus flowers are rich in amino acid, which is prime building block of keratin [8]. Keratin is the protein that nourishes, strengthens, and binds the hair roots thereby stimulating hair growth [9]. Natural ingredients, such as butterfly pea flower (*Clitoria ternatea*), offer alternative treatments as an anti-dandruff. Butterfly pea flower, known for its antifungal, antimicrobial, anti-inflammatory, and antioxidant properties, contains flavonoids known as cysteine-rich antifungal proteins (CRAFP) in its flowers, seeds, stems, and leaves [10]. Neem is medicinal plant they are used as traditionally from ancient year in various herbal medicines such Ayurveda, Siddha, and Homeopathic [5]. Neem extracts have shown significant antimicrobial activity against fungi such as Malassezia, which is commonly associated with dandruff [11].

Natural pigments derived from plants, microalgae, and cyanobacteria not only provide vibrant coloration but also offer health benefits, including antioxidant and anti-inflammatory properties [5]. The present study aims to develop a shampoo using plant-based pigments extracted from neem leaves, fenugreek seeds, hibiscus flowers, and butterfly pea flowers. These natural pigments not only impart eco-friendly coloration but also provide scalp benefits

such as promoting hair growth, reducing dandruff, and supplying antioxidants and essential nutrients. Their incorporation into shampoo formulations offers a holistic and safer alternative to synthetic dyes.

2. Objectives

1. To identify the specific plant parts (flowers, fruits, leaves, or roots) with the highest concentration of natural pigments.
2. To assess the color stability and cosmetic properties of the extracted natural pigments in shampoo formulations.
3. To formulate a safe and effective shampoo incorporating plant-based pigments as a natural alternative to synthetic dyes.
4. To evaluate the performance of the natural pigment-based shampoo in terms of color retention, stability, scalp compatibility, and overall cosmetic efficacy.

3. Morphology of the Plants

To develop a shampoo, we extracted four different types of plant-based pigments using reflux extraction techniques. Each plant source provided distinct pigments:

1. Hibiscus produces a deep brick-red pigment.
2. Butterfly pea generates a vibrant indigo pigment.
3. Neem leaves yield a soothing green pigment.
4. Fenugreek seeds produce a warm yellowish pigment.

3.1 Hibiscus (Hibiscus rosa-sinensis)

Hibiscus rosa-sinensis, commonly known as red hibiscus, belongs to the Malvaceae (mallow) family [12]. It is a species of tropical hibiscus classified under the Hibisceae tribe and is considered native to East Asia. The plant thrives in subtropical and tropical regions and is extensively cultivated as an ornamental plant across Asia [13]. The flowers of Hibiscus sabdariffa are rich in anthocyanins, which are responsible for the red coloration and serve as a valuable source of natural pigments [14].

3.2 Butterfly pea (*Clitoria ternatea* L.,)

Clitoria ternatea L., commonly known as butterfly pea, belongs to the Fabaceae family. It is also referred to as Asian pigeonwings or bluebell vine. The plant is widely distributed across India, China, Central and South America, as well as East and West India. It produces large, showy purple flowers, typically 1-3 inches long [15]. The primary anthocyanin in butterfly pea is delphinidin, which contributes to its deep blue to purple coloration [16]. In Ayurvedic medicine, butterfly pea has been traditionally used to treat indigestion, constipation, fever, arthritis, sore throat, skin diseases, and eye ailments, while its seeds function as a laxative and are used to alleviate colic and swollen joints [17].

3.3 Neem (*Azadirachta indica*)

Azadirachta indica, commonly known as neem, belongs to the Meliaceae family. Azadirachtin, nimbin, nimbidin, and other flavonoids and polyphenols are among the bioactive substances that are connected to the natural green tint in neem extract, which gives it its advantageous skin-benefitting qualities [18-19].

3.4 Fenugreek

Trigonella foenum-graecum L., commonly known as fenugreek, belongs to the Fabaceae family. The flavonoids, saponins, and alkaloids found in fenugreek seeds have antioxidant and other health-promoting qualities that may help maintain the general health of the skin and hair [20]. It is widely cultivated in India, Afghanistan, Nepal, Iran, Argentina, Egypt, Pakistan, Spain, Turkey, France, Morocco, and North Africa [21].

4. Methodology

4.1 Extraction of Plant Materials

The plant materials used in this study were collected from local farmers and households in Wardha, Maharashtra. The selection of plant sources was based on their high pigment content, bioactive properties, and traditional use in hair care applications. The shades of the color pigments may vary depending on plant growth conditions, geographical location, and environmental factors. To ensure uniformity in pigment quality, careful control of the concentration and extraction process was implemented.

4.1.1 Extraction of Pigments from Hibiscus and Butterfly Pea

To obtain natural colorants from hibiscus (*Hibiscus rosa-sinensis*) and butterfly pea (*Clitoria ternatea* L.), a water distillation process was used. These plants were selected due to their antioxidant and antimicrobial properties, making them suitable for cosmetic applications, particularly in shampoo formulations.

Procedure

1. Weighed 10 g each of dried hibiscus and butterfly pea powder.
2. Rinsed a round-bottom flask with ethanol to ensure sterility.
3. Transferred the measured plant powder into the flask.
4. Added 100 g of distilled water to the flask.
5. Placed the flask on a heating mantle and subjected the mixture to reflux conditions for 6 hours at 50°C.
6. After the extraction process, the decoction was filtered to remove solid residues.
7. The filtrate was placed on a hot plate set at 50°C and allowed to evaporate until a concentrated pigment extract was obtained.
8. The final extract was stored for use as a natural pigment/colorant in the shampoo formulation.

4.1.2 Extraction of Pigments from Neem Leaves

For neem (*Azadirachta indica*), the extraction method focused on obtaining the natural green pigment from the leaves.

Procedure

1. Fresh neem leaves were collected and washed thoroughly with water to remove impurities.
2. The leaves were grated properly to facilitate juice extraction.
3. The juice was extracted from the grated leaves by applying gentle pressure.
4. The extracted juice was filtered using muslin cloth to remove fibrous residues.
5. The final neem extract was collected and stored for use as a natural pigment/colorant in the shampoo formulation.

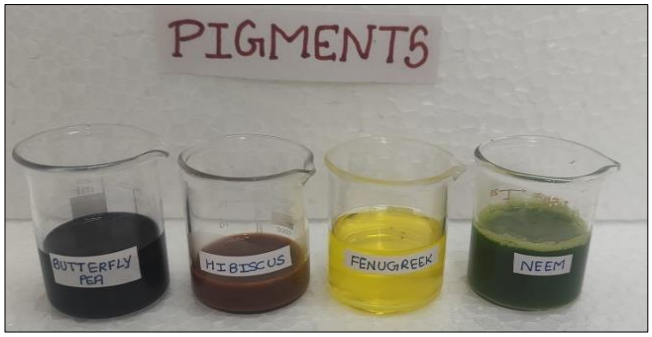
4.1.3 Extraction of Pigments from Fenugreek Seeds

For fenugreek (*Trigonella foenum-graecum* L.), a soaking method was used to obtain the yellow pigment extract.

Procedure

1. Weighed 10 g of fenugreek seeds.

2. Added 50 g of distilled water to the seeds.
3. Allowed the mixture to soak for 12 hours to facilitate pigment extraction.
4. Filtered the decoction to separate the yellow pigment filtrate from the solid residue.
5. The final fenugreek extract was collected and stored for use as a natural pigment/colorant in the shampoo formulation.



4.2 Formulation of Transparent and Pearl Shampoo:

The formulation composition used in this study are listed in Table 1. All ingredients were accurately measured before the preparation process began.

Procedure

Sodium Lauryl Ether Sulphate (SLES) and water were heated to 70-80 °C with continuous stirring until the surfactants completely dissolved and formed a homogeneous solution. The mixture was then allowed to cool down to 40 °C. Coco Amido Propyl Betaine (CAPB), Coco Diethanolamide, and Propylene Glycol were added gradually with gentle stirring to ensure uniform dispersion. These ingredients enhance viscosity, foam stabilization, and conditioning properties of the shampoo. In a separate beaker, sodium benzoate is mixed with until completely dissolved. This solution was then transferred into the surfactant mixture, functioning as a preservative system to prevent microbial contamination. Ethylene Glycol Monostearate (EGMS) was heated to 50-60 °C until melted and then added to the surfactant solution. EGMS provides an opaque, pearlescent texture to the shampoo. The extracted plant pigments were added to the shampoo mixture while stirring continuously to ensure uniform color distribution. The pH was adjusted using a 5% citric acid solution to achieve the desired pH level. Citric acid helps maintain the pH balance, which can influence color stability in the final formulation [22-23]. The shampoo was stored in airtight container to rest for 24 hours before evaluation to ensure proper stabilization.

Table 1: Composition of Shampoo:

S. No	Ingredient	Transparent Shampoo Quantity in gm	Pearl Shampoo Quantity in gm
1.	Sodium Lauryl Ether Sulphate (SLES)	50	50
2.	Coco Amido Propyl Betaine (CAPB)	10	9
3.	Coco diethanolamine	05	3
4.	Water	25	24.7
5.	Citric acid	1	1
6.	Propylene Glycol	5	4.7
7.	Pigments	4.8	4.8
8.	Ethylene Glycol Monostearate (EGMS)	-	2.8

Fig 1: Transparent Shampoo

Fig 2: Pearl Shampoo

5. Evaluation of Physio-Chemical Parameters

The quality and performance of shampoo are assessed through various physicochemical parameters that determine its effectiveness, stability, and safety. These parameters are essential for ensuring that the shampoo formulation meets cosmetic regulatory standards and provides optimal cleansing, foaming, and conditioning properties.

5.1 Determination of pH: The pH was determined at in the pH meter equipped with glass electrode at the temperature 27 ± 2 °C. In case of liquid shampoo, pH was read directly in the sample in the pH meter.

5.2 Determination of Non-volatile alcohol soluble matter

Since the developed shampoo is surfactant-based, the non-volatile alcohol-soluble matter is determined by extracting the alcohol-soluble components, removing volatile substances,

and calculating the residue after evaporation by BIS Standards.

5.2.1 Procedure
Weighed accurately 10 g of the shampoo sample into a beaker and evaporated on a steam bath until nearly dry. Digested the residue with 50 mL of 96% ethyl alcohol, heating on a steam bath for 2 minutes. Filtered the hot alcoholic solution through a sintered glass funnel into a Buchner flask with suction. Wash the beaker and residue in the sintered funnel five times using 30 mL portions of hot ethyl alcohol. Transferred the filtrate in the Buchner flask into a weighed, wide-mouth flat-bottomed flask. Evaporated nearly to dryness on a water bath. Removed remaining alcohol by blowing a gentle stream of dry air while rotating the flask in a water bath. Dried the residue in an air oven at 105 °C until constant mass is obtained.

5.2.2 Calculation of Non-Volatile Alcohol Soluble Matter
Mass, % of residue (Y) = Mass of residue obtained × 100 / Mass in g, of the material taken for test

5.2.3 Chloride Content Determination
Dissolved the residue in 50 mL of distilled water and added 2 drops of methyl red indicator. Neutralized with dilute nitric acid (dropwise) until pink color appears. Titrate with standard silver nitrate solution using 2.5 mL of potassium chromate solution as an indicator until a brown color appears. Performed a blank determination using the same reagents but without the sample.

5.2.4 Calculation of Sodium Chloride Content

Sodium Chloride (%) (X): V X 0.5844/M

Where:
V = Volume of silver nitrate solution used for the sample minus the blank.
M = Mass of sample.

5.2.5 Calculation of Non-Volatile Alcohol Soluble Matter

Non-Volatile Alcohol Soluble Matter (%) = Y - X

Where:
Y = Mass % of residue
X = Sodium chloride (%)

5.3 Determination of Foam Height
The foam height test is conducted to evaluate the foaming ability of the developed shampoo under specific experimental conditions as per the BIS Standards. The foam generated in the shampoo solution provides information into its detergent efficiency, surfactant performance, and consumer acceptance. This test is performed using the foam height apparatus equipped with a pipette and receiver as per the BIS standard procedure.
Set up the foam height apparatus with a water jacket and maintain a circulating water temperature of 30 ± 2 °C. Rinsed the receiver with distilled water and ensured that the water drains down the walls in an unbroken film, indicating cleanliness. Prepared the 50 mL of the shampoo solution and transfer it into the receiver using a pipette. Adjusted the stopcock so that the solution level is exactly at the 50 mL mark in the receiver. Filled the pipette to the 200 mL mark with the shampoo solution using slight suction. Place the pipette at the top of the receiver and open the stopcock to release the solution into the receiver. As soon as the solution has run out of the pipette, start the stopwatch and record the initial foam height (highest point of the foam column). After 5 minutes, record the final foam height to assess foam stability. Measure the foam height at the highest average height reached by the foam rim.

Calculation
Recorded the values of Initial Foam Height (cm), Foam Height after 5 minutes (cm)

Foam Stability= Foam height after 5 min / Initial foam height ×100

5.4 Surface Tension Measurement
Surface tension is a critical parameter in evaluating the wetting, spreading, and foaming properties of shampoo formulations. A lower surface tension improves the spreading ability of the shampoo on hair and enhances cleansing efficiency. In this study, the surface tension of a 10% shampoo dilution in distilled water was measured using a stalagmometer at room temperature. The data was calculated by following equation given below:

R2 = (W3-W1) x N1 x R 1/ (W2 -W1) x N 2

Where:
W_1 = Weight of empty beaker
W_2 = Weight of beaker with distilled water
W_3 = Weight of beaker with shampoo solution
N_1 = Number of drops of distilled water
N_2 = Number of drops of shampoo solution
R_1 = Surface tension of distilled water at room temperature
R_2 = Surface tension of the shampoo solution

5.5 Percent of solid contents
The solid content in a shampoo formulation represents the amount of active ingredients, surfactants, and conditioning agents present after the evaporation of volatile components. This test helps assess the concentration and effectiveness of the shampoo formulation. The test is performed by completely evaporating the sample to dried shampoo solids and recorded the weight (W_3).
The percentage of solid contents is calculated using the formula:

% Solids= (W3−W1)/ W2−W1) ×100

Where:
W_1 = Weight of the empty evaporating dish
W_2 = Weight of evaporating dish with shampoo before heating
W_3 = Weight of evaporating dish with dried shampoo solids

5.6 Color Stability testing
Color stability is an important parameter in shampoo formulations, as changes in color may indicate chemical degradation, instability of dyes, or ingredient interactions over time. Stability testing helps evaluate the resistance of the shampoo's color under controlled conditions of temperature and humidity.
The transparent and opaque shampoo formulations were stored in a stability chamber at 40 ± 2°C and 75 ± 5% RH for

90 days. Control samples were stored at room temperature for comparison. Observations were recorded at regular intervals (e.g., Day 0, Day 30, Day 60, and Day 90).

5.7 Viscosity
Viscosity is a critical property of shampoo formulations that affects product application, spreadability, and user experience. A well-formulated shampoo should be viscous enough to stay on the hand before application but should also spread easily over the scalp and rinse off without leaving residue. The viscosity of the shampoos was determined by using Brookfield Viscometer.

5.8 Antimicrobial efficacy test of Shampoo
The antimicrobial efficacy of the shampoo was evaluated to assess its ability to inhibit microbial growth. The microbial test results for Total Viable Count (TVC) and the presence of gram-negative pathogens are presented in Tables 1 and 2.
According to BAM Chapter 3, the Total Viable Count (TVC) was found to be within acceptable limits, with values in the range of BLQ (LOQ - 10). Additionally, tests for gram-negative pathogens, including *Escherichia coli* and *Pseudomonas aeruginosa*, confirmed their absence in the tested samples, as per ISO 7251.

5.9 FTIR (Fourier Transform Infrared) spectrum comparison of Butterfly Pea Pigment and Butterfly Pea Shampoo
FTIR (Fourier Transform Infrared) spectrum comparison of Butterfly Pea Pigment and Butterfly Pea Shampoo was performed in Perkin Elmer Instrument. The major absorption peaks in both spectra indicate the presence of similar functional groups, confirming that the pigment's core structure remains intact after incorporation into the shampoo formulation. Some peaks show minor shifts in wavenumbers, suggesting potential interactions between the pigment and shampoo ingredients (e.g., surfactants, preservatives, or stabilizers). The Peaks at 3357.53 cm^{-1} and 3369.68 cm^{-1} (O-H), 1636.36 cm^{-1} and 1634.33 cm^{-1} (C=O), confirm the presence of flavonoids and anthocyanins, essential for antioxidant activity and colour retention. The stronger C-H peaks 2924.91 cm^{-1} in the shampoo suggest the presence of emollients, fatty acids, or conditioning agents that contribute to hair softness and nourishment.

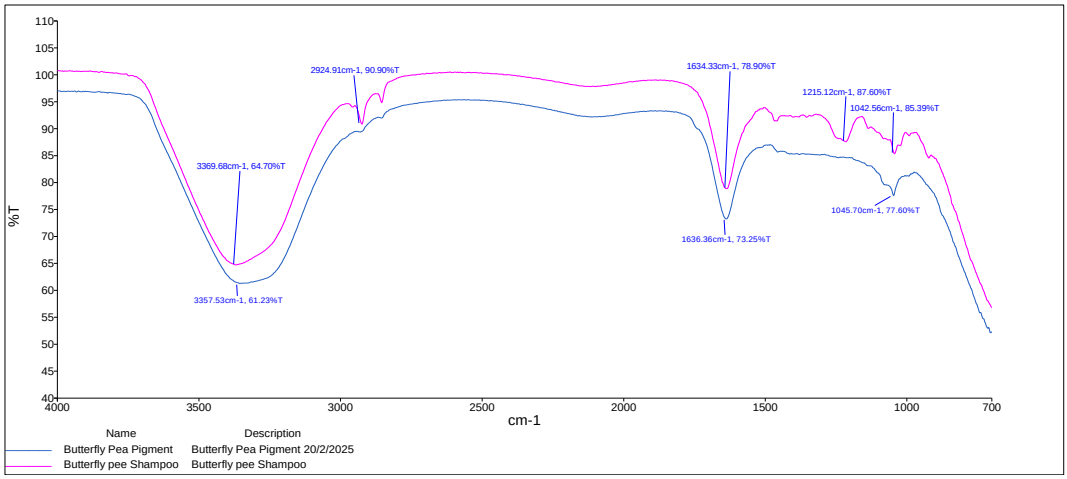


Fig 3: Comparative FTIR Spectrum of Butterfly Pea Pigment and Shampoo

5.10 FTIR (Fourier Transform Infrared) spectrum comparison of Hibiscus Pigment and Shampoo
The FTIR spectra of hibiscus pigment and hibiscus shampoo were analysed to interpret the retention of bioactive compounds, including flavonoids (quercetin) and anthocyanins, which contribute to colour, antioxidant activity, and scalp benefits. The -OH stretching band 3352.32 and 3364.50 cm^{-1} are slightly broader in the shampoo, indicating strong hydrogen bonding with surfactants. The C=O peaks at 1636.22 cm^{-1} and 1633.14 cm^{-1} confirm that the anthocyanins in hibiscus pigment remain stable in the shampoo, ensuring long-lasting natural coloration. The C-H stretch 2925.74 cm^{-1} appears in the shampoo spectrum, likely due to lipids or natural emollients incorporated for better hair conditioning.

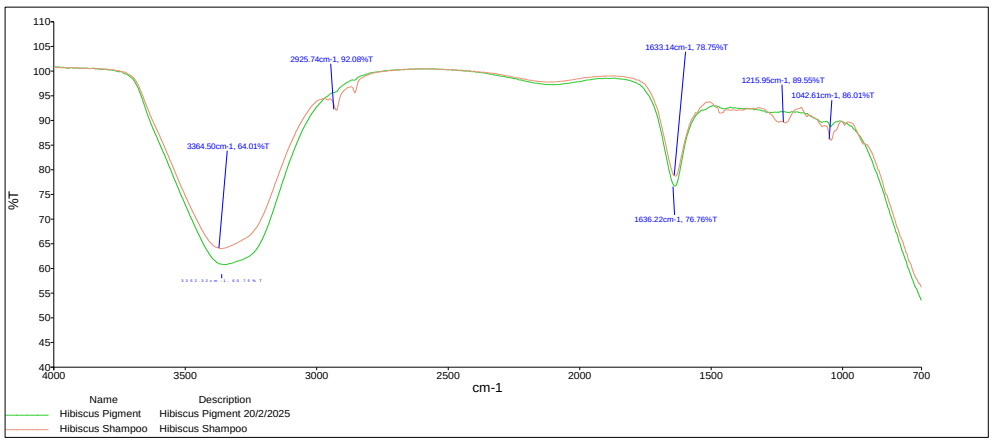


Fig 4: Comparative FTIR Spectrum of Hibiscus Pigments and Shampoo

5.11 FTIR (Fourier Transform Infrared) spectrum comparison of Neem Pigment and shampoo.

Neem (*Azadirachta indica*) leaf contains bioactive compounds such as azadirachtin, nimbin, nimbidin, and flavonoids, which contribute to its antibacterial, antifungal, and scalp-soothing properties. The FTIR spectra comparison of neem pigment and neem shampoo helps determine the functional group retention and interaction with shampoo excipients.

The O-H stretching region 3346.25 cm^{-1} and 3360.41 cm^{-1} confirms the presence of phenolic compounds and flavonoids, indicating the preservation of neem's antioxidant and antimicrobial properties in the shampoo. A slight shift in the C=O at 1638.94 cm^{-1} and 1635.51 cm^{-1} suggests interaction between neem bioactives and shampoo surfactants, enhancing solubility and bioavailability. The increased intensity of C-H peaks 2926.14 cm^{-1} in the shampoo indicates fatty acid and surfactant interactions, which contribute to improved hair conditioning and smoothness.

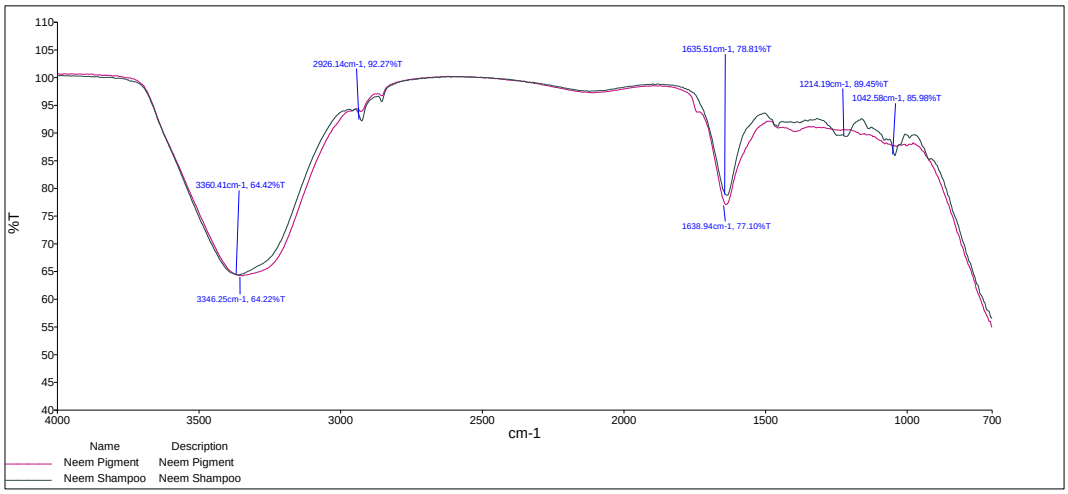


Fig 5: Comparative FTIR Spectrum of Neem leaf Pigments and Shampoo

5.11 FTIR (Fourier Transform Infrared) spectrum comparison of Fenugreek Pigment and shampoo.

Fenugreek (*Trigonella foenum-graecum*) contains flavonoids, steroidal saponins, alkaloids (trigonelline), and polyphenols, which contribute to hair strengthening, anti-dandruff, and scalp nourishment properties. The peaks at 3278.96 cm^{-1} and 3376.01 cm^{-1} (O-H), 1638.91 cm^{-1}-1744.21 cm^{-1} and 1638.91 cm^{-1} (C=O), and 1539.05 cm^{-1} (C=C) peaks confirm the presence of flavonoids, alkaloids, and saponins in the shampoo. The increase in C-H stretching 2853.52 cm^{-1} and 2924.33 cm^{-1}-2926.72 cm^{-1} indicates better incorporation of lipids and conditioning agents in the shampoo.

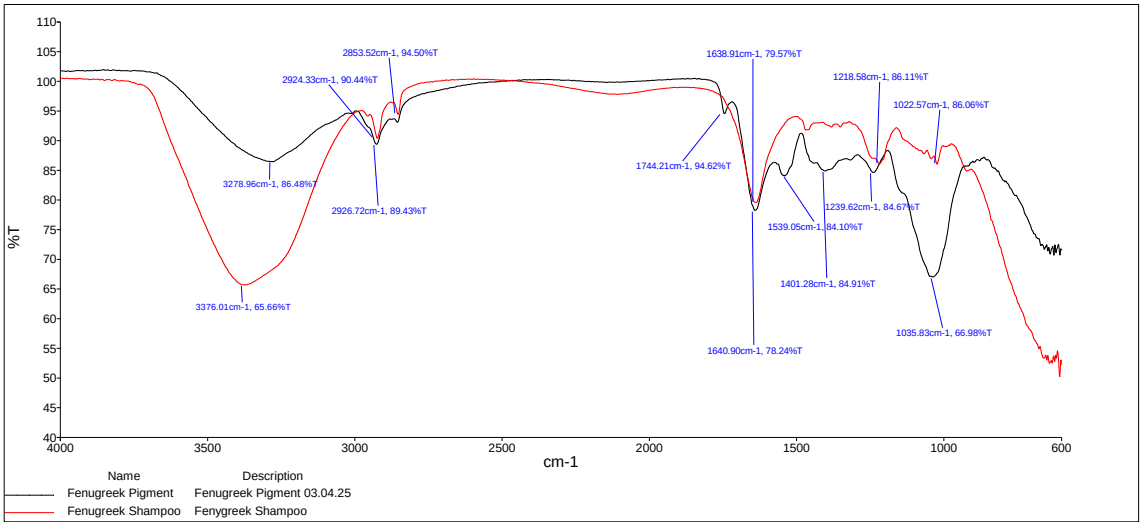


Fig 6: Comparative FTIR Spectrum of Fenugreek Pigments and Shampoo

6. Results and Discussion

Natural Plant base pigment used in the formulation of shampoo. These plants were Neem, Guava, Hibiscus and Butterfly pea has been reported for Antioxidant and Antimicrobial properties for Hairs. The various quality control parameters like pH, Non-volatile alcohol soluble matter, foam height, Microbial Examination, Surface tension, Percent of solid content, Stability of pigment, Viscosity were checked. The pH of both transparent and opaque shampoos was found to be 6.52, which is within the ideal range for shampoo formulations. This ensures scalp compatibility, prevents excessive dryness or irritation, and maintains hair health. he non-volatile alcohol-soluble matter was measured as 19.597% for transparent shampoo and 19.5957% for opaque shampoo. This indicates that the surfactant system in both formulations is consistent and stable. The foam height was recorded at 190 mm for both formulations. This demonstrates that the shampoos produce an adequate amount

of foam, which is an important consumer preference factor. The good foamability indicates the presence of effective surfactants in the formulation. Both transparent and opaque shampoos had a surface tension of 29.00 mN/m, suggesting that the surfactant system is well-balanced, ensuring effective wetting and spreading on the scalp and hair. Both formulations remained stable under thermal stress conditions, confirming their physical stability and resistance to phase separation or degradation at elevated temperatures. The solid content was found to be 20.25% in both formulations. This ensures the presence of an adequate amount of active ingredients and excipients necessary for product efficacy. Both shampoo formulations were observed to be liquid in nature with a smooth texture, indicating good formulation consistency without any precipitation or phase separation. The color of both formulations was Red, Green, Yellow, and Blue, depending on the added dye. The fragrance was found to be pleasant, making the shampoo aesthetically appealing for consumers. The Total Viable Count (TVC) was found to be Below Limit of Quantification (BLQ: LOQ-10), which ensures that the formulation is free from microbial contamination and has an effective preservative system. No Gram-negative pathogens (Escherichia coli and Pseudomonas aeruginosa) were detected in either formulation. This confirms that the shampoo meets microbiological safety standards as per ISO 7251 and is safe for consumer use.

FTIR analysis confirms that all four pigments retain their functional bioactive compounds, making them suitable for use in herbal cosmetic formulations. Each pigment has unique properties that contribute to hair health, conditioning, and antimicrobial benefits.

Table 2: The results of Physio-Chemical Evaluation

Sr. No	Evaluation Parameters of Shampoo		Observation	
			Transparent Shampoo	Opaque Shampoo
1.	Physio-Chemical Evaluation	pH value	6.52	6.52
		Non-volatile alcohol soluble matter	19.597	19.5957
		Foam Height value[mm]	190mm	190mm
		Surface tension measurement mN/m	29	29
		Thermal stability	No phase separation	No phase separation
		Solid content (%)	20.25	20.25
		Viscosity (cps)	68.20	68.41
2.	Organoleptic Evaluation	Physical Appearance	Liquid	Liquid
		Texture	Smooth	smooth
		Color	Red, Green, Yellow, Blue.	Red, Green, Yellow, Blue.
		Odour	Pleasant	Pleasant
3.	Microbial Evaluation	Total viable count (cfu/g)	BLQ (LOQ-10)	BLQ (LOQ-10)
		Gram negative pathogens.	Absent	Absent

Table 3: The results of stability testing

Test/Month	Transparent Shampoo				Opaque Shampoo			
	Initial Month	After 1 Month	After 2 Month	After 3 Month	Initial Month	After 1 Month	After 2 Month	After 3 Month
Physical Appearance	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid	Liquid
Texture	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth	Smooth
Color Stability	Stable	Stable	Stable	Stable	Stable	Stable	Stable	Stable
Odour	Pleasant	Pleasant	Pleasant	Pleasant	Pleasant	Pleasant	Pleasant	Pleasant
pH value	6.52	6.52	6.57	6.60	6.52	6.52	6.56	6.62
Foam Height value[mm]	190mm	190mm	190mm	190mm	190mm	190mm	190mm	190mm
Thermal stability	ok	ok	ok	ok	ok	ok	ok	ok
Viscosity (cps)	68.20	68.20	68.18	68.13	68.41	68.41	68.38	68.35
Total viable count (cfu/g)	BLQ (LOQ-10)	BLQ (LOQ-10)	BLQ (LOQ-10)	BLQ (LOQ-10)	BLQ (LOQ-10)	BLQ (LOQ-10)	BLQ (LOQ-10)	BLQ (LOQ-10)
Gram negative pathogens	Absent	Absent	Absent	Absent	Absent	Absent	Absent	Absent

6.1 Ideal Properties of Developed shampoo

The developed shampoo formulation fulfils all ideal shampoo properties as per BIS standards, ensuring superior cleansing, conditioning, and consumer satisfaction. The following key parameters were evaluated: The shampoo exhibits an optimal viscosity, ensuring it stays in the hand before application. It spreads easily and disperses quickly over the scalp and hair, providing uniform cleansing. The formulation rinses out effortlessly with water, leaving no sticky or greasy residue. Ensures a fresh, clean feel after washing. After rinsing, hair is soft, smooth, and easy to comb both when wet and dry. Prevents excessive tangling and enhances hair manageability. Infused with a mild and refreshing scent that enhances the user experience. The fragrance is non-irritating and long-lasting after application. The shampoo has a low irritation potential, making it gentle on the scalp and eyes. Free from harsh surfactants that could cause dryness or irritation. Properly preserved against bacterial and fungal contamination to maintain product integrity. Microbial analysis confirmed Total Viable Count (TVC) within acceptable limits and the absence of harmful pathogens (*E. coli, P. aeruginosa*). The shampoo remains stable for at least 2-3 years at room temperature without phase separation, color changes, or microbial growth. Tested under accelerated storage conditions to confirm its long-term stability. The formulation is simple yet effective, avoided overuse of unnecessary additives. Contains balanced active ingredients that promote healthy hair without excessive formulation complexity.

7. Conclusion

This study successfully demonstrated the extraction, formulation, and application of plant-based natural pigments in the development of an eco-friendly shampoo. The pigments derived from Hibiscus, Butterfly Pea, Neem Leaves, and Fenugreek Seeds not only provided vibrant, natural colors but

also imparted beneficial bioactive properties, making them a viable alternative to synthetic dyes.

This study highlights the potential of herbal cosmetics in replacing synthetic dyes and harsh chemicals with safe, bioactive plant extracts. The findings support the use of plant-derived pigments for the development of sustainable, non-toxic, and effective personal care products, aligning with the growing consumer preference for natural and eco-friendly cosmetics. Overall, the findings suggest that natural pigment-based shampoos have the potential to be a safer, sustainable, and consumer-preferred alternative to synthetic formulations.

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