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Physicochemical and Spectral Properties of Herbal Hair Oils Available in Local Market of Bangladesh

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Abstract

Herbal hair oils are widely used for their nourishing and therapeutic properties, offering scalp conditioning and treatment of hair disorders with minimal side effects. This study evaluated the physicochemical and sensory properties of nine commercially available hair oils to assess their quality, safety, and compliance with cosmetic standards. Parameters analyzed included color, odor, sensitivity/irritation, pH, specific gravity, acid value, saponification value, iodine value, and peroxide value. All samples were non-irritant with acceptable pH, but some showed deviations in other parameters. Oils like Hamdard, Navratna, and Rangapori largely met standards, whereas Farjana and Sesa exhibited oxidative instability, indicating potential formulation issues. Findings highlight the need for strict quality control and proper storage to ensure safety, stability, and consumer acceptability. It was observed that all of the tested herbal oils showed some UV protection capabilities showing the highest SPF values around 7.0.

Keywords*: Herbal Hair Oil, Physicochemical Properties, Sensory Evaluation, Safety Assessment, Quality Control, Oxidative Stability, SPF, Cosmetic Standards.*

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সারমর্ম: চুলের ভেষজ তেলগুলি তাদের পুষ্টিকর এবং থেরাপিউটিক বৈশিষ্ট্যের জন্য ব্যাপকভাবে ব্যবহৃত হয়, যা ন্যূনতম পার্শ্বপ্রতিক্রিয়া সহ মাথার ত্বকের কন্ডিশনিং এবং চুলের রোগের চিকিৎসা প্রদান করে। এই গবেষণায় নয়টি বাণিজ্যিকভাবে উপলব্ধ চুলের তেলের ভৌত রাসায়নিক এবং সংবেদনশীল বৈশিষ্ট্য মূল্যায়ন করা হয়েছে যাতে তাদের গুণমান, সুরক্ষা এবং প্রসাধনী মানগুলির সাথে সম্মতি মূল্যায়ন করা যায়। বিশ্লেষণ করা পরামিতিগুলির মধ্যে রয়েছে রঙ, গন্ধ, সংবেদনশীলতা/জ্বালা, pH, আপেক্ষিক ঘনত্ব, অ্যাসিড মান, স্যাপোনিফিকেশন মান, আয়োডিন মান এবং পারক্সাইড মান। সমস্ত নমুনা গ্রহণযোগ্য pHসহ জ্বালা-পোড়াহীন, তবে কিছু অন্যান্য পরামিতিগুলিতে বিচ্যুতি দেখিয়েছে। হামদর্দ, নবরত্ন এবং রাঙ্গাপুরির মতো তেলগুলি মূলত মান পূরণ করেছে, যেখানে ফারজানা এবং সেসার মতো তেলগুলি অক্সিডেটিভ অস্থিতিশীলতা প্রদর্শন করেছে, যা সম্ভাব্য ফর্মুলেশন সমস্যাগুলি নির্দেশ করে। অনুসন্ধানগুলি সুরক্ষা, স্থিতিশীলতা এবং ভোক্তাদের গ্রহণযোগ্যতা নিশ্চিত করার জন্য কঠোর মান নিয়ন্ত্রণ এবং সঠিক সংরক্ষণের প্রয়োজনীয়তা তুলে ধরে। পরীক্ষিত সমস্ত ভেষজ তেলগুলি কিছু UV সুরক্ষা ক্ষমতা দেখিয়েছে যা সর্বোচ্চ SPF মান 7.0 এর কাছাকাছি।

1. Introduction:

Hair is one of the most distinctive features of mammals and plays vital biological, social, and aesthetic roles. Throughout history and across civilizations, scalp hair has been regarded as a symbol of beauty, vitality, and power, whereas baldness or hair loss has often been associated with negative attributes such as aging or loss of strength [1]. To address hair-related concerns, a variety of hair care preparations, particularly hair oils, have been traditionally employed for the prevention and treatment of conditions such as baldness, premature graying, dandruff, split ends, and hair breakage [2]. In addition to therapeutic functions, these oils are widely used to promote hair growth, improve scalp health, and enhance overall hair appearance. Among various types, herbal hair oils have gained significant popularity as they are formulated with natural plant-based ingredients that exhibit nourishing, therapeutic, and conditioning properties. These formulations typically combine herbs, flowers, fruits, and essential oils to target diverse scalp and hair concerns [3]. Commonly used components include coconut oil, castor oil, amla oil, jojoba oil, rosemary oil, lavender oil, and peppermint oil, each contributing specific phytoconstituents known to support hair growth, strengthen strands, and prevent damage [4]. The synergistic action of multiple herbal ingredients in a single formulation is believed to provide enhanced efficacy compared to individual agents alone [5].

Herbal hair oils are generally massaged into the scalp to enhance blood circulation, stimulate follicles, and deliver deep nourishment [6]. Unlike synthetic hair care products, which may contain harsh chemicals and potential irritants, herbal formulations are valued for their safety, minimal side effects, and long history of use in traditional medicine systems such as Ayurveda and Unani [7]. Consequently, consumer preference has shifted considerably toward natural alternatives in the cosmetic and personal care industry.

Given the wide availability of herbal hair oil brands in the market, standardization of their physicochemical properties is essential to ensure quality, safety, and efficacy. Parameters such as color, odor, specific gravity, pH, saponification value, iodine value, acid value, and peroxide value are widely employed for quality control and compliance with international standards, including those prescribed by the Bureau of Indian Standards (BIS), the International Organization for Standardization (ISO), and the East African Standards (EAS). The present study aims to evaluate the physicochemical parameters of selected herbal hair oils available in the market of Bangladesh, thereby contributing to their standardization and quality assurance [8]. In this study ATR-FTIR spectra of the oil samples were taken and analyzed. The UV-Vis spectra were taken with 200-400 nm to check the characterestic peaks of the samples. UV-Vis analysis was also used to determine the *in vitro* Sun Protection Factor (SPF) of herbal oils with the Mansur equation [9].

2. Material and methods

2.1 Sample Collection

A total of nine hair oil samples, namely, Sesa Herbal Hair Oil, Emami Seven Hair Oil, Bajaj Almond Hair Oil, Himani Navratna Hair Oil, Hamdard Amla Hair Oil, Rangapori Hair Oil, Kumarica Hair Oil, Farjana Onion Hair Oil, and Pumpkin Hair Oil, were collected from various local markets across Bangladesh. Some important physicochemical parameters, like colour, odour, sensitivity, skin irritation, pH, specific gravity, acid value, saponification value, iodine value, and peroxide value, were analyzed using standard analytical methods to evaluate the quality of the collected samples.

2.2 Methods

2.2.1 Colour and Odour

The colour of hair oil was first examined visually by transferring 20–30 mL into a clear glass vial and observing against a matte white background under neutral daylight-equivalent illumination (Illuminant D65) at 27 ± 2°C. The method requires the oil to be free from sediment or suspended matter at this temperature and to possess a colourless or declared colour appearance. Odour was assessed using sensory descriptive analysis with a trained panel of 8–10 assessors, selected and tested in individual booths conforming to ISO standards [8].

2.2.2 Sensitivity and Skin Irritation Test

The prepared hair oil was applied to a 1 cm^2 area of the skin on the back of the hand and exposed to sunlight for 4–5 minutes to check for any adverse reactions such as redness, itching, or irritation. Observations were recorded immediately after exposure and after 24 hours to ensure skin compatibility. The skin irritation test was performed by applying a small amount of the hair oil to a defined area of the skin (approximately 1–2 cm^2) and leaving it in contact for 10 minutes. After removal, the skin was observed for any redness, swelling, or itching immediately and after 24 hours. These procedures followed standard guidelines for *in vivo* skin irritation assessment of cosmetic safety evaluation [10].

2.2.3 pH

The pH of the sample oils was measured with the help of EAS 847-17 method [11] by using EZDO pH meter (Model PH-5011). The pH meter was calibrated with buffer solutions (pH 7 and pH 4), and the electrode was rinsed with distilled water. The oil sample was placed in a clean beaker without air bubbles, the electrode was immersed and gently stirred, and the stabilized pH reading was recorded.

2.2.4 Specific Gravity

To determine specific gravity, standard method [12] was used. A clean, oven-dried specific gravity bottle (pycnometer) is weighed empty (W_1), with sample (W_2), and with water (W_3). Using the known density of water (d_1), the sample's density and specific gravity were calculated as:

Density of sample, $d_2 = (W_2 – W_1) \div \{(W_3 – W_1)/d_1\}$

Specific gravity of sample = $(d_2 \div d_1)$

2.2.5 Acid Value

Standard method was employed to determine the acid value of oil [12]. About 0.6–0.8 g of oil was dissolved in hot 95% alcohol, cooled, and titrated with 0.1N KOH using phenolphthalein, with a blank run under identical conditions. The acid value was calculated as:

$$\text{Acid value} = \frac{\left[\left(S - B\right) \times N \times 56.1\right]}{W}$$

Where, S = KOH volume for sample, B = KOH volume for blank, N = KOH strength.

2.2.6 Saponification Value

To determine Saponification value, standard method [12] was used. About 0.6–0.8 g of oil was refluxed with alcoholic KOH then the excess alkali was titrated with ¼ N HCl using phenolphthalein, with a blank run under identical conditions. Then saponification value is calculated with the help of following equation:

$$\text{Acid value} = \frac{\left[\left(V_2 - V_1\right) \times f \times 56.1\right]}{W}$$

Where, f = HCl strength, W = sample weight, V_2 = blank HCl volume, V_1 = sample HCl volume.

2.2.7 Iodine Value

Standard Wijs method was employed to determine the iodine value of oil [12]. A measured oil sample (10-13 drops) was dissolved in $CHCl_3$, treated with Wijs solution, kept in the dark for 1 hour, then reacted with KI and titrated with 0.1 N sodium thiosulphate using starch indicator, with a blank run. Then iodine value was calculated using the following relation:

$$\text{Iodine value} = \frac{\left[\left(V_2 - V_1\right) \times f \times 0.127 \times 100\right]}{W}$$

Here, f= strength of $Na_2S_2O_3$, W= weight of oil taken, V_1 = volume of $Na_2S_2O_3$ for sample, V_2=volume of $Na_2S_2O_3$ for blank.

2.2.8 Peroxide Value

To determine peroxide value, standard method [12] was used. About 0.3 g of oil was dissolved in chloroform–acetic acid, treated with KI, kept in the dark, diluted, and titrated with 0.01 N $Na_2S_2O_3$ using starch indicator, with a blank run. Then peroxide value was calculated using the following relation:

$$\text{Peroxide Value (meq per 1000g)} = \frac{(V \times N \times 1000)}{W}$$

Here, W= Weight of oil, N=Normality of $Na_2S_2O_3$, V= Volume of $Na_2S_2O_3$

2.3 Spectrophotometric Characterization

2.3.1 Infra-red spectrophotometry

Attenuated total reflectance-Fourier transform infrared (ATR-FTIR) spectra were recorded using a PerkinElmer Spectrum Two FTIR spectrometer with ATR (Model: Spectrum two, UK). The instrument was turned on and stabilized for 15–30 minutes, the oil/fat sample placed on the ATR crystal, spectral parameters set, and a scan initiated for analysis. Proper sample preparation and alignment ensured accurate results.

2.3.2 UV-vis spectrophotometry

The herbal oil was dissolved in a suitable solvent, such as ethanol, and placed in a UV-transparent cuvette (made of quartz or special plastic) for analysis and the spectrum was taken between 200 and 400 nm using a Smimadzu (UV-1100) UV-Vis spectrophotometer.

2.3.3 Determination of Sun Protection Factor

A stock solution of the herbal oil at concentration 1% v/v was prepared in a suitable solvent (e.g., n-hexane or ethanol). The stock solution is further diluted to an appropriate concentration for analysis (e.g., 0.1%). The absorbance of diluted sample solution was measured using a UV-Vis spectrophotometer in the range of 290 to 320 nm at 5 nm intervals, using the pure solvent as a blank. Sun Protection Factor was calculated by the following Mansur equation **[9].**

$$SPF\,(spectrometry) = CF \times \sum_{290}^{320} EE\,(\lambda) \times I(\lambda) \times abs(\lambda)$$

Where, the standard erythemal effect, EE (λ) × solar radiation intensity, I (λ) values and the correction factor (CF=10).

3. Result and Discussion

In this study, spectral characterizations and key physicochemical parameters—colour, odour, sensitivity, skin irritation, pH, specific gravity, acid value, saponification value, iodine value, and peroxide value—were determined for nine

herbal hair oils, and the results are presented in Table 1 and 4. The corresponding standard values are shown in Table 2.

3.1 Color and Odor

The analyzed hair oils exhibited color and odor typical of their constituents, which is expected due to the natural pigments and volatile compounds in raw materials. These sensory traits are essential for consumer acceptance and also serve as indicators of product quality and stability [13]. Any deviation may indicate oxidation or adulteration, affecting shelf life and safety [14]. The typical color and odor observed confirm the authenticity and stability of the tested oils.

Table 1. Sensory properties of the analyzed hair oils

Sample Name	Colour	Odour	Irritation & Sensitivity
Sesa	Green	Aromatic	Non-irritant
Emami	Yellow	Characteristic	Non-irritant
Bajaj	Yellow	Characteristic	Non-irritant
Navratna	Red	Aromatic	Non-irritant
Hamdard	Green	Characteristic	Non-irritant
Rangapori	Green	Characteristic	Non-irritant
Kumarica	Green	Characteristic	Non-irritant
Farjana	Brown	Squishy	Non-irritant
Pumpkin	Green	Characteristic	Non-irritant

Table 2. Standard values of different physicochemical parameters of hair oil.

Standard[1,3,4] pH	Standard[3,4] specific gravity	Standard[1,5] acid value (mg KOH/gm)	Standard[5] saponification value (mg KOH/gm)	Standard[2,5] iodine value (g I_2 /100g)	Standard[1,5] peroxide value (meq/kg)
4 - 7	0.900 - 0.940	≤1.00	117.87 - 224.2	<120	≤10.00

[1]BSTI; [2]US, [3]WHO, [4]ISO, [5]AOCS

3.2 Sensitivity and Skin Irritation

All the tested hair oils were found to be non-irritant, confirming their safety for cosmetic and topical use. The absence of irritation indicates that the formulations are compatible with the scalp's physiological condition and do not disrupt the skin barrier [15]. Non-irritant products minimize the risk of erythema, itching, or allergic reactions in topical applications [16].

3.3 pH

All analyzed hair oils had pH values within the safe cosmetic range of 4–7 [17], with Hamdard Amla Hair Oil showing the highest pH (7.0) and Farjana Onion Hair Oil the lowest (5.5). pH influences both product stability and scalp compatibility, as lower pH indicates higher free fatty acids from triglyceride degradation, while higher pH suggests better oxidative stability and longer shelf life [18]. Maintaining pH near the scalp's natural acidity (4.5–5.5) is crucial for scalp health, and observed variations likely reflect differences in raw materials, processing, and storage [15].

3.4 Specific Gravity

Specific gravity, reflecting the purity and density of hair oils, should range from 0.900–0.940 [19]. In this study, only Sesa and Hamdard (0.92) met this standard, while others—Emami (0.82), Bajaj (0.86), Navratna (0.88), Rangapori (0.86), Kumarica (0.87), Farjana (0.85), and Pumpkin (0.85)—were lower. These deviations may indicate adulteration, poor-quality raw materials, or improper processing, potentially reducing stability and consumer acceptability [20].

3.5 Acid Value

In the present analysis, acid values of most samples were within the standard range (≤ 1.00 mg KOH/g). However, Sesa (1.01 mg KOH/g) slightly exceeded the limit, while Farjana (2.64 mg KOH/g) showed a significantly higher value. Elevated acid values suggest increased free fatty acids due to hydrolytic or oxidative degradation of triglycerides, often accelerated by poor raw material quality, improper storage, or extended shelf life [20]. High free fatty acid content not only reduces stability and shelf life but may also affect sensory quality and scalp compatibility [14, 20]. Therefore, strict monitoring of acid value is essential to ensure product safety and consumer acceptance.

3.6 Saponification Value

In this study, Navratna (222 mg KOH/g), Hamdard (210 mg KOH/g), and Rangapori (127 mg KOH/g) were within the standard (117.87–224.2 mg KOH/g), while Emami (66 mg KOH/g), Bajaj (76.7 mg KOH/g), Kumarica (87 mg KOH/g), and Pumpkin (19 mg KOH/g) were much lower. Conversely, Sesa (368 mg KOH/g) and Farjana (323 mg KOH/g) exceeded the upper limit. Low values may reflect adulteration with

long-chain or non-edible oils, whereas high values suggest excess short-chain fatty acids or formulation errors [18, 20]. Thus, maintaining saponification values within limits is crucial for stability and consumer safety.

3.7 Iodine Value

In this study, all samples complied except Farjana (120.5 g I_2/100g), which slightly exceeded the standard limit (<120 g I_2/100g). Higher iodine values indicate greater unsaturation, making oils more prone to rancidity and shorter shelf life, while lower values suggest better oxidative stability [18, 20]. Thus, most oils tested were within safe limits, but the elevated value in Farjana may compromise stability and storage quality.

Table 3. Physicochemical parameters of the analyzed hair oils

Sample Name	pH	Specific gravity	Acid value (mg KOH/g)	Saponification value (mg KOH/g)	Iodine value (g I_2 /100g)	Peroxide value (meq/kg)
Sesa	5.9	0.92	1.01	368	89.8	6.72
Emami	6.3	0.82	0.98	66	70.1	2.35
Bajaj	6.8	0.86	0.84	76.7	82.4	3.0
Navratna	6.6	0.88	0.82	222	93.2	3.2
Hamdard	7.0	0.86	0.98	210	80.3	2.1
Rangapori	6.7	0.87	0.86	127	78.4	3.1
Kumarica	5.5	0.85	0.95	87	74.1	5.61
Farjana	5.5	0.92	2.64	323	120.5	18.25
Pumpkin	6.8	0.85	0.64	19	77.6	2.81

3.8 Peroxide value

Peroxide values of all the analyzed hair oils were within the standard (≤10 meq O_2/kg), except Farjana (18.25 meq O_2/kg) which far exceeded the limit. Elevated peroxide value suggests significant oxidative deterioration, likely due to poor storage, light/heat exposure, or inferior raw material quality [14, 18, 20, 21]. Oils with high peroxide value not only have reduced shelf life but may also develop undesirable odor and reduced consumer acceptability. In contrast, the relatively low peroxide values in most samples (2.1–6.72 meq O_2/kg) indicate good oxidative stability and proper handling. Figure 1 shows the comparative peroxide values of herbal oils analyzed.

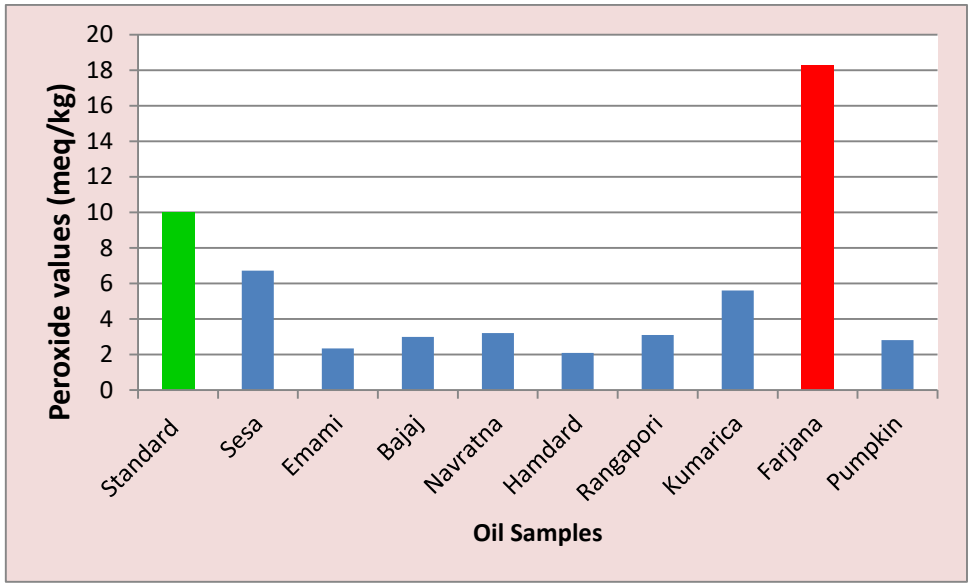

Figure 1. Comparative peroxide values of herbal oils analyzed.

4. Spectral Characterizations

4.1 FTIR spectroscopy

The integration of FTIR spectroscopy with traditional physicochemical analyses offers a comprehensive approach to evaluate oil quality and authenticity. Overall, the FTIR analysis of all the oil samples revealed that they primarily consist of typical components such as triglycerides, fatty acids, and aliphatic hydrocarbon chains, confirming their expected chemical composition without any unusual modifications or adulteration. FTIR spectroscopy allows the identification of specific chemical bonds such as C=O, C-H, and O-H, which are indicative of fatty acid composition, oxidation levels, and potential adulteration [22]. A rrepresentative FTIR spectrum of herbal oil (Sample-Hamdard) has been presented in Figure 2**.**

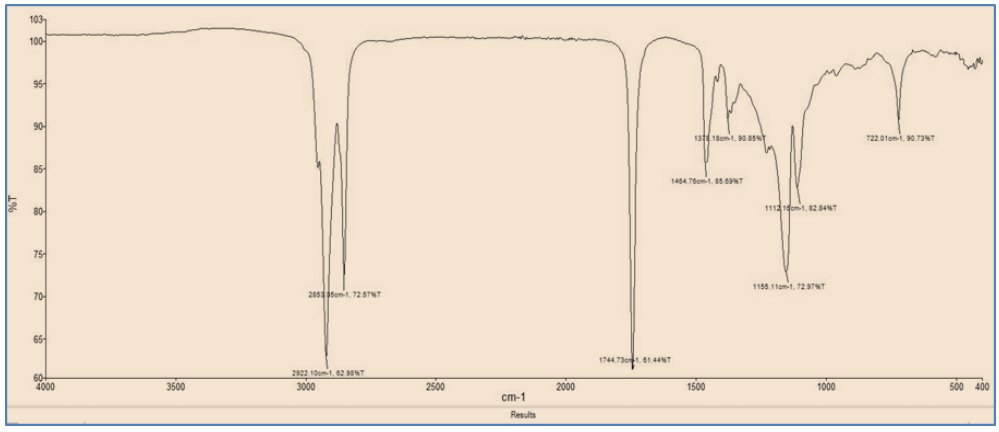

Figure **2**: Representative FTIR Spectrum of herbal oil. (Sample-Hamdard)

4.2 UV-Vis **spectroscopy**

The UV-Vis spectrum of oil shows a strong absorption peak at around 292 nm in the UV region, which indicates its ability to absorb UV radiation and offers some protection for the skin. The spectrum also shows a peak at approximately 205 nm, corresponding to the n→π* transition of the saturated fatty acids, especially the ester carbonyl groups, which are abundant in herbal oils. This absorption is relevant for its use in products where UV protection is desired.

4.3 Sun Protection Factor

Studies showed that herbal oils possess adequate SPF values (SPF ~7) when used alone. Comparative Sun Protection Factor (SPF) of herbal oils analyzed has been given in Figure 3. While useful for screening, these oils are typically sufficient for adequate sun protection on their own. therefore, they can serve as excellent ingredients in formulated herbal sunscreens. Herbal oils are known to be safe and have been widely accepted by consumers. Along with their many beneficial effects and safety, these botanicals could become good, cheap and easily available formulation ingredients in sunscreen products.

Table 4: Spectrophotometrically determined sun protection factor of herbal oils.

Sample Name	290 nm		300 nm		310 nm		320 nm		SPF values
	EE×I	Abs.	EE×I	Abs.	EE×I	Abs.	EE×I	Abs.	
Sesa	0.015	0.6223	0.2874	0.6203	0.1864	0.6154	0.018	0.6105	**7.17**
Emami		0.6104		0.6100		0.6094		0.6054	**7.07**
Bajaj		0.6054		0.6004		0.5954		0.5854	**6.93**
Navratna		0.5858		0.5818		0.5808		0.5758	**6.74**
Hamdard		0.6537		0.6517		0.6507		0.6437	**7.55**
Rangapori		0.5315		0.5300		0.5285		0.53215	**6.16**
Kumarica		0.5397		0.5347		0.5297		0.5257	**6.18**
Farjana		0.5759		0.5719		0.5659		0.5609	**6.61**
Pumpkin		0.5156		0.5126		0.5106		0.5056	**5.93**

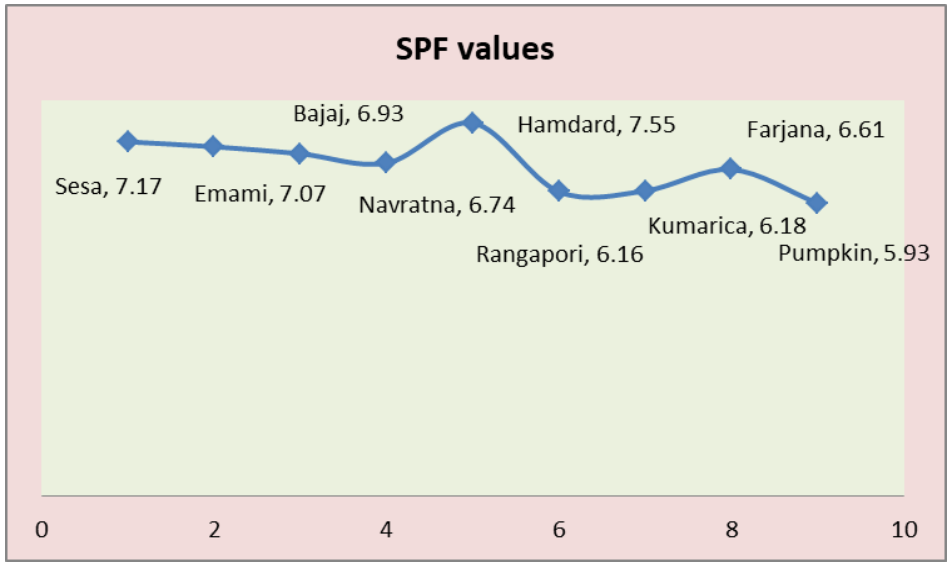

Figure 3. Comparative Sun Protection Factor (SPF) of herbal oils analyzed.

5. Conclusion

The physicochemical evaluation of nine commercial herbal oils revealed that most products maintained acceptable colour, odour, pH, and non-irritant properties, confirming their basic suitability for cosmetic use. FTIR and UV-vis spectral studies characterized them well. However, significant variations were observed in specific

gravity, acid value, saponification value, iodine value, and peroxide value, indicating inconsistencies in raw material quality, processing, and storage. Oils such as Hamdard, Navratna, and Rangapori were generally closer to standard requirements, whereas Farjana and Sesa frequently exceeded critical limits, reflecting reduced stability and potential safety concerns. These findings suggest that while some brands comply with international standards, others require strict monitoring to ensure consumer safety and product reliability. Most of them showed well sun protection level showing SPF values around 7.00. Findings highlight the need for strict quality control and proper storage to ensure safety, stability, and consumer acceptability.

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