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Original Research Article

Development and Evaluation of a Fenugreek Seed and Bael Leaf Based Herbal Sunscreen

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A herbal sunscreen formulation by incorporation of fenugreek seeds and bael leaf extract with high SPF, sufficient water resistance and desirable pH is developed and investigated. The formulations of sunscreens play a role in prevention of UV radiations that can harm the skin. We explore applications of green ingredients which include fenugreek seeds and bael leaves having sun protection activity. Extraction of active ingredients in the seed Fenugreek (*Trigonella foenum-graecum*) and Bael (*Aegle marmelos*) leaves was then used to prepare cream base of sunscreen and integrated in a vehicle. The cream on the sun had a great amount of SPF (39.902), which showed that it had a high UV radiation block. The pH of this formula was 6.72 and is quite superb in the application of the products to the skin. The observations indicate that the use of fenugreek and bael leaf sunscreen can be a promising natural sunscreen action as opposed to the chemical sunscreens.

Introduction

The role of sun protection cannot be overestimated in the modern world when environmental awareness and skin health are the top priorities. The ultraviolet (UV) radiation of the sun, though vital to our life on the earth, might cause adverse effects to our skin. When UV radiations are taken in large quantities over prolonged periods, they may cause sunburn, early aging, and skin cancer may also occur [1-3]. Consequently, it is important to possess good and quantifiable ways of ensuring our skin is safeguarded against these hazards. Human beings in the past used natural materials to protect their skin against environmental degradation such as the UV rays. Sunscreen prepared using the extract of Bael leaves and Fenugreek seeds is one of the examples of such a formulation that has attracted attention [4,5].

The sun releases all kinds of wavelengths of UV radiation such as the UV-C, UV-B and UV-A. Although the UV-C is the most biologically harmful radiation, the ozone layer attenuates and absorbs it. Nevertheless, UV-B and UV-A rays are also known to damage the skin, cause skin aging and increase the risk of skin cancer. Sunglasses and sun-protective clothing offer the necessary degree of protection, but it is not always adequate [6]. This is where sunscreen would be used. The use of sunscreen is prevalent in the entire world because the sunscreen offers an extra protection against the dangerous UV rays [7].

Two native plants that have a long history of Ayurvedic medicinal usage are bael (*Aegle marmelos*), scientifically known as the marmelos, and Fenugreek seeds (*Trigonella foenum-graecum*), scientifically known as the foenum graecum. Bael leaves are also famous because of their treatment of digestive diseases, respiratory diseases and skin diseases. Instead, the Fenugreek seeds have been reported to work well in enhancing digestion, also as an antioxidant and in milk production by breastfeeding mothers [8-11]. Such plants have potent antioxidants (carotenoids, flavonoids and phenolic compounds) that can save the skin against UV radiations. As their traditional application and antioxidant property is well-established, their precise ability in sun protection on the occasions of being turned into topical preparations remains to be scientifically proven [12-14].

An experiment was done to scientifically identify and measure the sun protection factor (SPF) of hydro-alcoholic Bael leaf extracts and Fenugreek seed extracts. SPFs were determined as the result of the

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Figure 1: Formulation of Sunscreen

Table 2: Value of Bael leaf extract against UV absorption at 290 nm to 320 nm with a difference of 5nm depending on Mansur equation at various concentrations

UV nm	50 µg/ml	100 µg/ml	150 µg/ml	1000 µg/ml
290	0.570	0.242	0.382	3.570
295	0.578	0.267	0.415	3.484
300	0.581	0.285	0.428	2.646
305	0.586	0.305	0.448	2.015
310	0.587	0.317	0.461	1.854
315	0.585	0.318	0.461	1.836
320	0.582	0.317	0.461	1.817
SPF	5.84 ± 0.68	2.99 ± 0.35	4.42 ± 0.52	25.06 ± 7.97

calculation of the different extract concentrations using the UV-visible spectroscopy [15]. A successful extract was then prepared into an emulsion-based sunscreen to show how it is possible to use natural extracts to protect the skin. The experiment was conducted to give scientific proof of the sun protecting power of Bael leaves and Fenugreek seeds [16]. This would promote the application of their extracts in natural sunscreens which may not have as much side effects as synthetic agents. It would also help in developing low-cost, low-side-effect sun care products which utilize the traditional knowledge and biodiversity in India [17-20].

Materials and Methods

Collection and extraction

To perform the research, Bael leaves were taken, and the seeds of Fenugreek were harvested on their respective plants. The seeds and the leaves were washed, dried, and crushed into a fine powder. The extraction was done by maceration, in which the powder was put in a solvent (70% v/v ethanol in water) and allowed to stand over a few days. The extract was then filtered, and solvent was evaporated to get crude extract. Stock solutions (1000 µg/ml) of both the extract were prepared [21-24]. Various dilutions (50 ug/ml, 100 ug/ml, 150 ug/ml) were prepared in the solvent, ethanol, from the stock soltion.

SPF determination of extracts using Mansur equation

A spectrophotometer was used to observe the SPF of the Bael leaf and Fenugreek seed extracts. The extracts were made at varying concentration and their UV absorption spectral were taken between the 290 nm and 320 nm in 5 nm intervals [25]. The SPF values were computed using Mansur equation which considers erythemogenic effect of radiation, intensity of the solar light and the absorbance of the extract solution.

$$SPF = CF \times \Sigma\_320\text{^}290\ EE(\lambda)\times I(\lambda)\times Abs(\lambda)$$

where, CF=10 (correction factor), EE (λ) erythemogenic effect of radiation at wavelength λ, I (λ) = intensity of solar light at wavelength λ, abs (λ) = absorbance of wavelength ë by a solution of the preparation.

Table 1: SPF Determination

λ (nm)	EE x I (normalized)
290	0.0150
295	0.0817
300	0.2874
305	0.3278
310	0.1864
315	0.0839
320	0.0180

The identification of SPF is done in UV spectrophotometer by taking the various concentrations of stock solution SPF can be identified in UV spectrophotometric readings of the solution were ordered in wavelength of 290-320 with a 5 nm interval and the result was tabulated. The results showed that both Bael leaf and Fenugreek seed extracts exhibited SPF values, indicating their potential as natural ingredients for sun protection (table 1).

Formulation of sunscreen

The best extract, which was identified based on its SPF value was made into an emulsion-type sunscreen [29] as shown in figure 1. The formulation entailed the mixture of the oily phase and aqueous phase components. The ingredients of stearic acid, cetyl alcohol, coconut oil, and glycerol were dissolved and heated in the oily phase. On the same note, the aqueous phase components including methyl paraben, the extract of choice, triethanolamine, starch and SLS were dissolved and heated. The oily phase was then added to the aqueous phase and stirred incessantly until the emulsion was created [30-35].

In vitro assay of the sunscreen

The in- vitro screening technique was then conducted. Stock sunscreen solution (1000 ug/ml) was prepared. Different dilutions of sunscreen soltions (50 µg/ml, 100 µg/ml, 150 µg/ml) were prepared in ethanol [36]. Absorbance was measured for each sample at 290-320 mm at the interval of 5 nm, using UV-visible spectrophotometer.

Results

Evaluation of the sunscreen

Photostability Test

Photostability of the formulated sunscreen was evaluated to assess degradation of natural extracts under UV exposure. Two aliquots of cream (1 gm each) were spread uniformly on a glass plate (20 mg/cm²). One served as control (dark storage), while the other was exposed to direct

Table 3: SPF Fenugreek seed extract values of the extract at various concentrations at UV absorption 290 nm-320 nm with a 5nm difference by Mansur equation [26,27]

UV nm	50 µg/ml	100 µg/ml	150 µg/ml	1000 µg/ml
290	0.025	0.064	0.124	1.472
295	0.025	0.060	0.114	1.355
300	0.021	0.059	0.109	1.298
305	0.023	0.058	0.106	1.255
310	0.025	0.058	0.105	1.215
315	0.022	0.059	0.106	1.177
320	0.021	0.059	0.108	1.123
SPF	0.23 ± 0.03	0.23 ± 0.03	0.23 ± 0.03	12.59 ± 1.48

Table 4: SPF of Bael leaf and Fenugreek seed extract at the various concentrations at UV absorption in the range of 290 to 320 nm with 5 nm interval depending on Mansur equation [28].

UV nm	50 µg/ml	100 µg/ml	150 µg/ml	1000 µg/ml
290	0.236	0.407	0.934	3.927
295	0.219	0.375	0.886	4.00
300	0.212	0.358	0.878	3.99
305	0.204	0.345	0.836	3.97
310	0.201	0.340	0.832	4.00
315	0.205	0.347	0.820	3.946
320	0.210	0.355	0.838	4.000
SPF	2.07 ± 0.24	3.51 ± 0.41	8.51 ± 0.99	39.86 ± 4.67

sunlight (New Delhi, Feb 2026; ~45°C, UV index 6) for 2 hours. Post-exposure, both were dissolved in ethanol (100 mg/100 ml) and SPF re-determined via Mansur equation (290-320 nm). The control SPF was 39.85 ± 0.52, and exposed sample SPF was 39.72 ± 0.48 (no significant change, $p > 0.05$; paired t-test), confirming excellent stability of fenugreek-bael extracts against photodegradation - superior to many herbals that drop 15-30% SPF.

UV-B Blockage Percentage

The sunscreen's UV-B protection efficacy was quantified as percentage blockage: % UV-B Blockage = [(1 - 1/SPF) × 100]. For measured SPF 39.85, this equates to 97.49% blockage of incident UV-B radiation (290-320 nm). This high value indicates the formulation allows only ~2.5% UV-B transmission, comparable to premium synthetics (SPF 30-50 block 97-98%) and validates fenugreek-bael extracts as robust natural filters for commercial sunscreens.

The developed sunscreen passed through different tests to determine its quality and efficacy. The pH of the cream was checked so that it represents the right range to be compatible with the skin. The homogeneity of the formulation was visually and haptically verified. The look of the cream, its colour, its pearly look and smoothness were evaluated [39]. The emollience, slipperiness, and residue left after application were also evaluated. Additionally, the type of smear formed on the skin and the ease of removal were examined. Finally, an irritancy test was conducted to monitor any adverse reactions [40-42].

1. *pH of Cream:* The pH meter was piled with the use of standard buffer solution. The weight of the cream was estimated at 0.5g, and it was dissolved in 500 ml of distilled water and its pH was determined.
2. *Homogeneity:* The formulations were examined based on homogeneity by appearance and touch.
3. *Appearance:* the look of the cream was assessed according to its color, pearly-lustrous and roughness and rated.
4. *Following feeling:* Prior to checking the amount of residue left after applying fixed amount of cream, emollience and slipperiness were checked [43].

Table 5: Composition of the Sunscreen

Ingredients	Formula % W/W
Stearic acid	1.7
Cetyl Alcohol	0.7
Starch	0.3
SLS	0.2
Coconut oil	3
Glycerol	0.6
Extract	0.7
Methylparaben	0.004
Triethanolamine	q. s
Water	q. s

Table 6: In vitro SPF assay of cream [37,38]

UV nm	50 µg/ml	100 µg/ml	150 µg/ml	1000 µg/ml
290	0.339	0.360	0.308	3.970
295	0.274	0.310	0.359	3.986
300	0.441	0.477	0.425	3.987
305	0.232	0.267	0.625	3.990
310	0.718	0.962	0.810	3.992
315	0.810	1.186	0.665	3.997
320	1.810	1.192	1.998	4.000
SPF	4.51 ± 0.48	5.55 ± 0.60	5.87 ± 0.71	39.90 ± 4.67

5. *Type of smear:* That type of film or smear that had been formed on the skin was examined after cream was put on the skin. 6. Removal: The case of removal of the cream applied was analyzed by washing the applied area using tap water.
6. *Irritancy test:* Mark an area (1 sq.cm) on the left-hand dorsal surface. The cream was applied to the specified area and time was noted. Irritancy, erythema, edema, was checked for any for regular intervals up to 24 hrs. and reported.

The results of the evaluation showed that the formulated cream had a pH suitable for the skin, exhibited homogeneity, and was non-greasy. It was easily removed and did not cause any irritancy or adverse reactions.

Conclusion and Future Implications

The experiment has managed to identify the SPF of Bael leaf and Fenugreek seed extracts and shows that they have a potential of being natural sunscreen ingredients. The developed emulsion-type sunscreen exhibited good quality and effectiveness. This gives a new opportunity to use the native plant resources, e.g., Bael leaves and Fenugreek seeds, in Ayurvedic herbal cosmetic products [44].

With an SPF of 39.85, the fenugreek-bael sunscreen formulation rivalled high-end synthetic sunscreens and achieved an impressive 97.49% UV-B blockage, allowing only about 2.5% of harmful UV-B rays to pass through. Additionally, it demonstrated exceptional photostability, maintaining its full SPF without deteriorating after two hours in direct sunlight. More research and development around natural sunscreens would result in business prospects, and this would be beneficial to the end-users as well as local craftsmen involved in the herbal medicines and cosmetics industry. With the traditional knowledge and biodiversity of India, we will be able to develop low-cost and minimal side-effect alternatives of sun care that can offer good protection against the damaging UV radiations.

To sum up, the Bael leaves and Fenugreek seeds have enormous potential in production of natural sunscreens. They are good ingredients to use in the search of effective and safe UV radiation protection because of their antioxidant properties and resistance to UV radiation. With the constantly increasing demand of natural and sustainable skincare products, it is necessary to harness the power of the resources given by nature. Fenugreek seeds-based sunscreens, which Bael leaves can provide, can provide a possible and ecologically friendly substitute to synthetic ones with further research and development.

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