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Research Article

Spectrophotometric Evaluation of the Sun Protection Factor of Wild *Sideritis raeseri* Extracts under Different Solvent and Temperature Conditions

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Abstract: Plant-origin sunscreen products for skin protection from ultraviolet radiation are preferred over synthetic products as safer with regard to possible toxicity, allergies, and are eco-friendly. This study fills a gap in peer review research for endemic Albanian wild mountain tea (*Sideritis raeseri Boiss & Heldr.*) for its ultraviolet photoprotective properties under various solvent types, incubation days, and temperatures, by utilizing the Mansur method. S. *raeseri* aqueous extracts were centrifuged, filtered, and then mixed in two Erlenmeyer flasks: one with distilled water and the other with ethanol in a 1:4 v/v ratio. Absorbance measurements within the 290-320 nm range were taken at different temperatures over six consecutive days. Neither water nor ethanol absorbs within this range. In extracts at room temperature (29-31 °C), Sun Protection Factor (SPF) value expressed as mean ± standard deviation dropped from 26.426 ± 0.2 on day one to 17.930 ± 0.19 on day six; for refrigerated extracts at 11 °C, SPF dropped from 26.426 ± 0.2 to 22.469 ± 0.19. In the water-ethanolic mixture at room temperature, SPF dropped from 23.281 ± 0.21 to 13.387 ± 0.036, and with refrigeration, from 23.281 ± 0.21 to 21.199 ± 0.21. At refrigerated conditions, the SPF of *S. raeseri* extract was photochemically more stable and showed a longer shelf-life, while SPF values at room temperature incubation were lower. Higher SPF values were found in water solutions than water-ethanol. The refrigerated water-ethanol mixture could be utilized in sunscreen products as a stability factor for SPF values of *S. raeseri* extracts.

Keywords: *Sideritis raeseri*, SPF, UV Protection, Natural Sunscreen, Mansur Method.

1. INTRODUCTION

The pathogenesis of skin cancer is multifactorial (sunburn, time of exposure, protection, etc.) were ultraviolet (UV) radiation is considered to be the main cause and risk factor, as mentioned by Fabris *et al.* [1]. The threat posed by UV radiation has brought along increased awareness among the population, leading to shorter intervals of sun exposure as well as a growing demand for various sun protection products. Increased awareness of UV damage has led to an increased trend of plant-based sunscreen protection products alongside the traditional products. According to Korac and Khambholja [2], conclusive proof suggests that a good quality sunscreen is safe to use when applied correctly; it reduces the risk of skin cancer. To this day, in general, including UV radiation, prevention was and still remains the best and most effective measure for public health protection. . Breitbart *et al*. [3] studied the effect of sun protection on reducing UV-related risks and found that using sun protection products that absorb or block UV radiation, proved to be a highly effective preventive measure. As proved by Raymond and Riskin [4], some synthetic chemical UV filters like oxybenzone, TiO_2, etc., pose a risk to human health, as with the Volatile Organic Components, as proved by Pal *et al*. [5]. Also, Suh *et al*. [6] underline the risk for human health of some of the ingredients of sunscreen creams. According to Wheate *et al* [7], the active pharmaceutical ingredients (API) in sun protection products may threaten the aquatic species, hence recent studies and innovative lab techniques are

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shifting towards plant-based sunscreen products as safer, effective, and eco-friendly alternatives. Discovering new sources of plant extracts with sunscreen properties that could serve to formulate creams or oils with sun-protective properties and finding their best conditions of storage to conserve their properties becomes of primary importance. By investigating the incubation period in various temperature conditions and solvents of the sun protection factor of *S. raeseri* this study aims to contribute to related cosmetic industries by highlighting the potential use of mountain tea as a natural ingredient.

As mentioned in several studies, such as Dutra *et al*. [8] or Zarkogianni and Nikolaidis [9], the Mansur spectrophotometric method is a widely accepted approach for determining the Sun Protection Factor (SPF) in vitro. In this study, the Mansur equation was used to analyze SPF values of the extracts of the endemic Albanian mountain tea, *Sideritis raeseri Boiss & Heldr (S. raeseri*), a plant known for its bioactive properties, in various solvents and at different incubation temperatures over several days.

The effectiveness of sun-protective products is measured by their SPF, which indicates the amount of UV energy required to cause a minimal erythema dose (MED) on protected skin versus unprotected skin.

$$SPF = \frac{MED-protected\ skin}{MED-unprotected\ skin} \quad (1)$$

While previously studies investigated with different methods the chemical compounds and their degradation in various conditions and solvents of *S. raeseri*, this study provides for the first time the influence on the stability of SPF of this plant in two different solvents, water and water-ethanol. This is particularly relevant for cream and oil formulations seeking to minimize synthetic UV filters due to concerns over allergenicity and toxicity, as proved by Stiefel and Schwack [10], as well as the environment pollution.

2. MATERIALS AND METHODS

2.1. The Plant

The wild Albanian "mountain tea", *Sideritis raeseri Boiss & Heldr*, belongs to the *Lamiaceae* family and was studied in this paper for its potential sunscreen properties under different solvents, time incubation, and temperatures with the Mansur "in vitro" method. This plant, typically found at elevations above 600 meters, is a mostly perennial herb that flourishes in calcareous, well-drained, slightly alkaline soils. It prefers rocky slopes with ample sunlight exposure, experiencing dry summers and mild winters.

The tea, made from an aqueous solution of its aerial parts (flowers, stems, and leaves), is widely used for its anti-inflammatory, analgesic, gastroprotective, and antimicrobial benefits, and serves as a dietary supplement for anaemia.

2.2. Plant Preparation

A quantity of 1g dried *S. raeseri* was chopped and precisely weighed using an analytical balance. The weighed sample was placed in an empty, heat-resistant glass beaker, and 50 mL of deionized water was added once it had begun to boil. Then the mixture was allowed to steep for 5 minutes, during which the chromophores began to release their characteristic colour. The resulting solution was cooled at room temperature and subsequently filtered using filter paper with a pore size of 1.2 μm and a nominal thickness of 260 μm. The filtered extract was transferred to a glass Erlenmeyer flask and stored at 3 °C in a refrigerator for 24 hours before analysis. After 24 hours, the solution was centrifuged at 4000 rpm for 8 minutes.

The resulting supernatant was then diluted at a 1:4 ratio with distilled water (e.g., 20 mL supernatant to 80 mL water, or 1 part supernatant to 4 parts 100% ethanol, corresponding to a 20% v/v dilution). The final concentration of the extract used for spectrophotometric measurements is, for both solutions, 4 mg/mL or 4% w/v. Both were prepared for spectrophotometric analysis. The prepared samples were stored at two different temperatures: 11 °C and 29-30 °C.

2.3. Spectrophotometry Measurement

Absorbance measurements were taken from 290 to 320 nm at 5 nm intervals(step) using a UV-VIS spectrophotometer (NADA 756s) with a 10 mm quartz cuvette, using distilled water and water-ethanol mixture as a blank. A blanking procedure for both types of solvents was executed before

starting the measurements. Water and water-ethanol mixtures as solvents do not interfere with UV absorption in tea-aqueous solutions, as they primarily absorb below the 290-320 nm interval. Each Optical Density (O.D) reading was repeated three times, and the SPF values were calculated with the Mansur formula. Measurements were performed daily over a total period of 6 days at two temperatures and with different solvents, including water and a water-ethanol mixture.

2.4. Mansur Formula

Several studies, as previously described [8-9], used the Mansur equation to calculate SPF by measuring the absorbance (from 290 to 320 nm with a 5 nm step) of diluted plant extracts. This "in vitro" method offers a reliable approach to assess the sun-protective properties of tea-aqueous solutions without requiring direct testing on humans against UVA and UVB. The SPF is calculated using the following equation (2):

$$SPF = CF\ x\ \sum_{290}^{320} EE(\lambda) x\ I(\lambda) x\ Abs(\lambda) \quad (2)$$

where *EE* is the erythemal effect spectrum, *I* is the solar intensity spectrum, $(EE(\lambda) x\ I(\lambda)$ is a constant, describing the relationship between the erythemal efficiency spectrum (EE) and the solar simulator intensity spectrum (I) at wavelengths from 290 to 320 nm, *Abs* is the absorbance of sunscreen products, and *CF* is the correction factor (=10).

2.5. Water and Ethanol Spectroscopic Properties as Solvents

Abou-Dahech *et al.* [11] emphasized the crucial role of solvents in the performance of UV filters. Both water and water-ethanol mixtures are solvents with non-aromatic, saturated molecules; their lowest-energy electronic transitions are σ→σ* or n→σ*, which require high energy, which is why the cutoff wavelength is set before 290 nm and doesn't interfere with the tea solutions' absorbance. Mason *et al*. [12], Shalatonin [13], and Saad *et al*. [14] suggested that water absorbance peaks in UVC at ~186 nm and a water-ethanol mixture of approximately 20% v/v absorb near 214 nm wavelength, and a second lower peak appears at ~280 nm [13]. Therefore, both solvents absorb UV light far before the interval of 290 - 320 nm.

2.6. Tea-aqueous Solutions and Their Spectroscopic Properties

Hodaj-Çeliku *et al*. [15] studied phenolic compounds, such as Carvacrol and Thymol, which have been found in high percentages (respectively 36.7% and 0.5% of total essential oils) in tea-aqueous solutions of *S. raeseri*, as well as essential oils including oxygenated monoterpene, oxygenated sesquiterpene, and sesquiterpene. While Carvacrol and Thymol (phenolic monoterpenes) do absorb in the interval 290-320 nm with a shoulder that falls gradually, oxygenated monoterpene, sesquiterpene do not affect absorption in this interval [16-17]. Carvacrol and Thymol both absorb UV light primarily because their chemical structure includes an aromatic ring and a functional hydroxyl group (-OH), and they contain a benzene ring with delocalized π electrons that absorb energy, with the possibility of undergoing π→π* electronic transitions. Also, Żyżelewicz *et al*. [18] in previous studies have reported that *S. raeseri* contains other aromatic photochemical compounds like flavonoids (Aspigenin, Luteolin, and their derivatives), which all absorb in the above-mentioned UV range due to their aromatic structure. All these compounds in the above-mentioned articles that are identified with spectrometric and HPLC-based methods create plant-origin filters against the UV radiation.

As proven by Romanucci *et al*. [19], compounds like Flavonoids (aglycones and glycosides) and Oxygenated monoterpene, sesquiterpenein, play an important role in scavenging free radicals and reducing oxidative stress by mitigating the damage caused by UV radiation. Espín *et al*. [20] studied that the antioxidant capacity has been positively correlated with phenolic content, and these compounds exert their antioxidant effects through several mechanisms. They stabilize free radicals generation from UV radiation by enhancing the photoprotective properties of the plant extract, besides improving sunscreen filters.

3. RESULTS AND DISCUSSION

This study investigated the effects of temperature and incubation period on the shelf-life stability of the SPF of *S. raeseri* in aqueous and water–ethanol mixed solutions as a possibility for use as plant-origin UV filters in sunscreen formulations.

Couteau *et al*. [21] found that the effect of the presence of ethanol on the efficacy of the filters and their photostability varies on the molecule considered. In Europe, Regulation (EC) No. 1223/2009 [22] currently authorizes 27 organic filters and two mineral filters (Titanium dioxide and Zinc oxide). The topical use of ethanol remains a subject of debate; however, Pendlington *et al.* [23] and Kramer *et al.* [24] have reported that ethanol is, *per se*, safe for topical use.

Tables 1, and 2 summarize triplicate O.D. measurements at seven wavelengths and the calculated SPF values in room temperature and refrigerated conditions, incubation periods, and water as solvent. The Standard Deviation (SD) has been calculated based on the Mean SPF values. The low variability of SD, ranging from 0.036 to 0.23 SPF units, and the Relative Standard Deviation (RSD) of less than 3%, indicates good repeatability and reliability of spectrophotometric measurements. Salazar-Orbea *et al*. [25] found that total polyphenols were more stable at 4 °C than at 24 °C, while Pavlovic *et al*. [26] proved that flavonoid content, due to their gradual degradation, decreases by 23% at 35 °C, and degradation was faster at higher temperatures than in refrigerated conditions, while compounds like phenolic monoterpenes are much more stable. They do evaporate in room conditions, but much less in refrigerated conditions. According to Soliman *et al*. [27], phenolic compounds (Carvacrol and Thymol in our study) were highly stable under various stress conditions, including oxidation, hydrolysis, and thermal decomposition. In water as a solvent, the drop of SPF in room conditions is related to evaporation and degradation processes, while the refrigerated conditions serve as a preservative by slowing these processes.

In Figures 1 and 2, SPF drops with respect to incubation period in both room and refrigerated conditions. The slope value of room temperature (-1.3511) versus that of refrigerated conditions (-0.8262) shows that both solutions are degrading (SPF decrease), but at room temperature, it occurs 1.63 times faster than in refrigerated conditions. The ongoing degradation at refrigerated conditions indicates that water alone is not the only problem,

Table 1. O.D. replicate measurements and SPF values for *S. raeseri* at 29 - 31 °C in water as solvent (n = 3).

Day	Rep\λ [nm]	290	295	300	305	310	315	320	SPF	Mean SPF	± SD
Day1	R1	2.88	2.826	2.749	2.653	2.561	2.483	2.427	26.619	26.426	0.2
	R2	2.84	2.786	2.709	2.613	2.521	2.443	2.387	26.23		
	R3	2.86	2.806	2.729	2.633	2.541	2.463	2.407	26.43		
Day2	R1	2.723	2.56	2.393	2.245	2.133	2.041	1.953	22.78	22.57	0.21
	R2	2.683	2.52	2.353	2.205	2.093	2.001	1.913	22.37		
	R3	2.703	2.54	2.373	2.225	2.113	2.021	1.933	22.57		
Day3	R1	2.582	2.449	2.308	2.178	2.089	2.019	1.951	22.08	21.9	0.18
	R2	2.542	2.409	2.268	2.138	2.049	1.979	1.911	21.72		
	R3	2.562	2.429	2.288	2.158	2.069	1.999	1.931	21.9		
Day4	R1	2.47	2.433	2.284	2.159	2.07	2.002	1.941	21.86	21.68	0.18
	R2	2.43	2.393	2.244	2.119	2.03	1.962	1.901	21.51		
	R3	2.45	2.413	2.264	2.139	2.05	1.982	1.921	21.68		
Day5	R1	2.474	2.341	2.208	2.095	2.013	1.972	1.903	21.22	21.04	0.18
	R2	2.434	2.301	2.168	2.055	1.973	1.932	1.863	20.86		
	R3	2.454	2.321	2.188	2.075	1.993	1.952	1.883	21.04		
Day6	R1	2.149	2.005	1.895	1.787	1.712	1.656	1.61	18.12	17.93	0.19
	R2	2.109	1.965	1.855	1.747	1.672	1.616	1.57	17.74		
	R3	2.129	1.985	1.875	1.767	1.692	1.636	1.59	17.93		

Table 2. O.D. replicate measurements and SPF values for *S. raeseri* at 11 °C in water solvent (n = 3).

Day	Rep\λ [nm]	290	295	300	305	310	315	320	SPF	Mean SPF	± SD
Day1	R1	2.88	2.826	2.749	2.653	2.561	2.483	2.427	26.619	26.426	0.2
	R2	2.84	2.786	2.709	2.613	2.521	2.443	2.387	26.23		
	R3	2.86	2.806	2.729	2.633	2.541	2.463	2.407	26.43		
Day2	R1	2.879	2.788	2.669	2.535	2.439	2.37	2.307	25.64	25.44	0.21
	R2	2.839	2.748	2.629	2.495	2.399	2.33	2.267	25.23		
	R3	2.859	2.768	2.649	2.515	2.419	2.35	2.287	25.44		
Day3	R1	2.867	2.776	2.65	2.516	2.416	2.331	2.278	25.41	25.22	0.19
	R2	2.827	2.736	2.61	2.476	2.376	2.291	2.238	25.03		
	R3	2.847	2.756	2.63	2.496	2.396	2.311	2.258	25.22		
Day4	R1	2.785	2.694	2.555	2.406	2.278	2.174	2.088	24.29	24.09	0.21
	R2	2.745	2.654	2.515	2.366	2.238	2.134	2.048	23.88		
	R3	2.765	2.674	2.535	2.386	2.258	2.154	2.068	24.09		
Day5	R1	2.613	2.525	2.404	2.273	2.17	2.087	2.016	22.96	22.77	0.19
	R2	2.573	2.485	2.364	2.233	2.13	2.047	1.976	22.58		
	R3	2.593	2.505	2.384	2.253	2.15	2.067	1.996	22.77		
Day6	R1	2.556	2.48	2.369	2.247	2.146	2.063	1.993	22.657	22.469	0.19
	R2	2.516	2.44	2.329	2.207	2.106	2.023	1.953	22.28		
	R3	2.536	2.46	2.349	2.227	2.126	2.043	1.973	22.47		

regardless of the low temperature, confirming that lower temperatures slow photochemical and oxidative degradation of phenolic constituents but do not stop it [27].

Tables 3 and 4 show the O.D. values in triplicate measurements and the mean SPF for the water-ethanol mixture at room and refrigerated temperatures. The SD calculated values range from 0.036 to 0.22 SPF units, with an RSD >2 % indicating good precision and repeatability of the spectrophotometric measurements.

At room temperature, the SPF decline is sharp and linear (Figure 3) with a negative slope, which confirms high volatility of Carvacrol and Thymol as well as oxidative degradation of flavonoids that affect the calculation of SPF with the Mansur formula [8]. At refrigerated conditions, the drop of SPF values for 6 consecutive days was 9% (Figure 5) and the slope for refrigerated condition -0.4666, both suggesting the role of low temperature in slowing the volatilization activity and oxidative degradation. This difference in the drop of SPF values between the two conditions could be attributed to the presence of ethanol in the mixture as a stabilizer, as reported by Plaskova and Mlcek [28]. As both water and ethanol–water mixture absorbs below 280nm, the observed differences arise from chemical stability, not from spectral overlap [11-12].

Figures 3 and 4 represent the SPF with respect to the incubation period in both conditions (room and refrigerated conditions). The differences in slope values in water-ethanol mixture at room temperature and refrigerated conditions are, respectively, -1.6795 and -0.4666 SPF units, which indicates a degradation is nearly 3.6 times slower in the refrigerated mixture.

The regression analysis in both Figures 3 and 4, based on R^2 value, reveals a stronger linear correlation for refrigerated conditions (R^2 = 0.8978) rather than room conditions (R^2 = 0.8112), indicating a more reliable prediction of degradation in the refrigerated conditions. At 29-30 °C, the degradation could be multifactorial, including evaporation, oxidative degradation of flavonoids, etc.

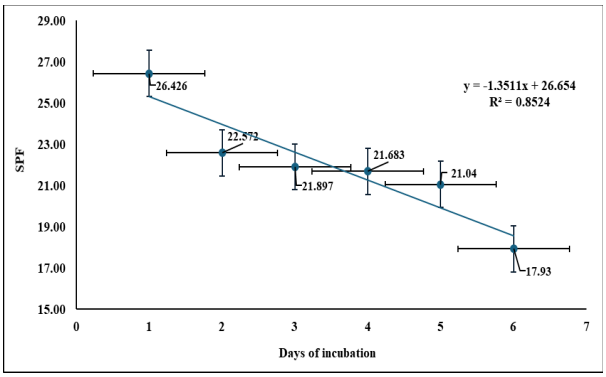

Fig. 1. SPF with respect to the incubation period at room temperature (water).

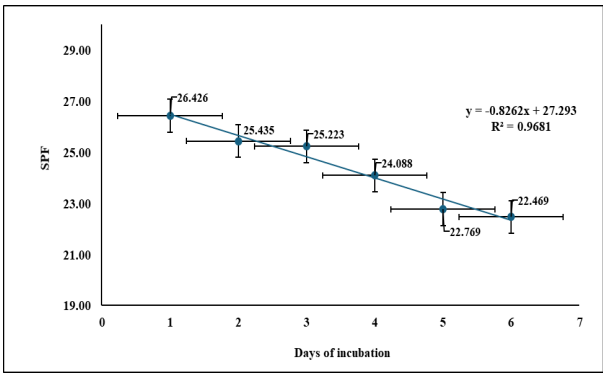

Fig. 2. SPF with respect to the incubation period at refrigerated conditions (water).

Table 3. O.D. replicate measurements and SPF values for *S. raeseri* at 29 - 31 °C in water–ethanol solvent (n = 3).

Day	Rep\λ [nm]	290	295	300	305	310	315	320	SPF	Mean SPF	± SD
Day 1	R1	2.365	2.42	2.4	2.35	2.293	2.24	2.211	23.341	23.281	0.21
	R2	2.325	2.38	2.36	2.31	2.253	2.2	2.171	23.211		
	R3	2.345	2.4	2.38	2.33	2.273	2.22	2.191	23.291		
Day 2	R1	2.17	2.06	1.936	1.838	1.773	1.731	1.525	18.48	18.42	0.056
	R2	2.122	2.012	1.892	1.796	1.734	1.694	1.495	18.37		
	R3	2.146	2.035	1.914	1.817	1.755	1.715	1.510	18.41		
Day 3	R1	1.861	1.742	1.652	1.571	1.524	1.492	1.468	15.79	15.736	0.051
	R2	1.802	1.699	1.603	1.53	1.483	1.454	1.43	15.69		
	R3	1.832	1.721	1.627	1.55	1.504	1.474	1.449	15.73		
Day 4	R1	1.951	1.781	1.645	1.542	1.484	1.451	1.424	15.61	15.547	0.055
	R2	1.902	1.731	1.598	1.501	1.444	1.413	1.387	15.61		
	R3	1.926	1.756	1.621	1.521	1.464	1.431	1.405	15.6		
Day 5	R1	1.821	1.718	1.603	1.536	1.487	1.459	1.431	15.42	15.379	0.041
	R2	1.777	1.672	1.563	1.499	1.451	1.423	1.395	15.348		
	R3	1.799	1.695	1.583	1.518	1.469	1.441	1.413	15.37		
Day 6	R1	1.481	1.438	1.391	1.344	1.326	1.307	1.283	13.42	13.387	0.036
	R2	1.437	1.398	1.347	1.303	1.285	1.267	1.241	13.35		
	R3	1.459	1.418	1.369	1.323	1.305	1.287	1.262	13.39		

Figure 5 shows that the SPF drop related to the first day is 43 % (from 23.28 to 13.39) at room temperature, and 9 % under refrigeration conditions (from 23.28 to 21.20), with the SPF value lower in the water-ethanol mixture. The difference between the first measurement of SPF in both conditions is about 11 % could be considered as normal or may be related to the addition of ethanol in the plant water extraction, creating a less polar solvent with a potential to alter the absorption band through a solvatochromatic effect, as reported by Shirali *et al*. [29].

Water-ethanol solvent at room temperature initially facilitates, by virtue of its being less polar, the solubility of phenolic compounds, but it seems to reduce the SPF value, likely due to its volatility and the increased oxidation of sensitive aromatic compounds. Their gradual photodegradation and oxidation account for the observed decline in SPF

Table 4. O.D. replicate measurements and SPF values for *S. raeseri* at 11 °C in water–ethanol solvent (n = 3).

Day	Rep\λ [nm]	290	295	300	305	310	315	320	SPF	Mean SPF	± SD
Day1	R1	2.365	2.42	2.4	2.35	2.293	2.24	2.211	23.341	23.281	0.21
	R2	2.325	2.38	2.36	2.31	2.253	2.2	2.171	23.211		
	R3	2.345	2.4	2.38	2.33	2.273	2.22	2.191	23.291		
Day2	R1	2.59	2.512	2.424	2.318	2.24	2.183	2.152	23.41	23.2	0.22
	R2	2.55	2.472	2.384	2.278	2.2	2.143	2.112	22.98		
	R3	2.57	2.492	2.404	2.298	2.22	2.163	2.132	23.2		
Day3	R1	2.57	2.483	2.384	2.283	2.203	2.144	2.117	23.05	22.83	0.22
	R2	2.53	2.443	2.344	2.243	2.163	2.104	2.077	22.61		
	R3	2.55	2.463	2.364	2.263	2.183	2.124	2.097	22.83		
Day4	R1	2.533	2.457	2.361	2.256	2.173	2.11	2.074	22.77	22.56	0.21
	R2	2.493	2.417	2.321	2.216	2.133	2.07	2.034	22.35		
	R3	2.513	2.437	2.341	2.236	2.153	2.09	2.054	22.56		
Day5	R1	2.609	2.457	2.361	2.256	2.173	2.11	2.074	21.54	21.31	0.23
	R2	2.569	2.417	2.321	2.216	2.133	2.07	2.034	21.09		
	R3	2.589	2.437	2.341	2.236	2.153	2.09	2.054	21.31		
Day6	R1	2.208	2.23	2.191	2.133	2.079	2.049	2.043	21.41	21.19	0.21
	R2	2.168	2.19	2.151	2.093	2.039	2.009	2.003	20.99		
	R3	2.188	2.21	2.171	2.113	2.059	2.029	2.023	21.18		

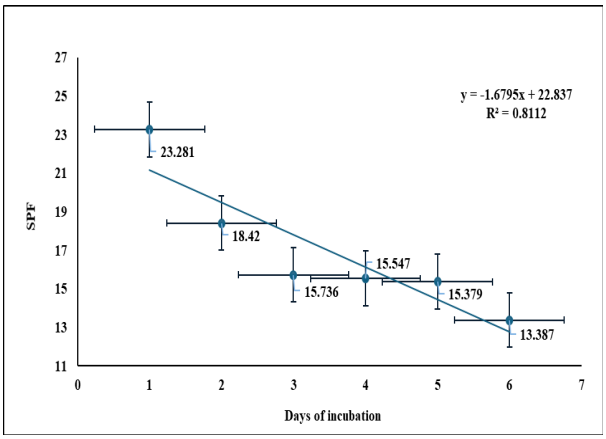

Fig. 3. SPF with respect to the incubation period at room temperature (water-ethanol).

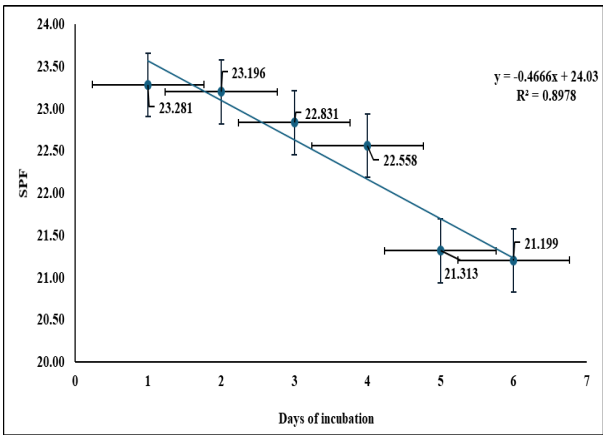

Fig. 4. SPF with respect to the incubation period at refrigerated conditions (water-ethanol).

during prolonged storage, particularly at higher temperatures or in ethanol–water mixtures, as reported by Galmarini *et al.* [30].

The statistical analysis of Table 5, using the Pearson correlation, revealed strong evidence of a true inverse linear relationship between SPF and its incubation time (days). The strongest correlation was observed in the water refrigerated extract (p = 1; r = -0.984), suggesting a highly linear, predictable decrease. On the other side, the statistical analysis shows r = -0.901 for room conditions in water-ethanol mixture, a slightly reduced value which may indicate that this mixture alters the degradation rate. The statistical analysis of Table 6 shows a strong relationship between the type of solvent and SPF values. The r values of 0.952 and 0.968 proved that the two solvents behave almost the same over time, regardless of initial differences in the magnitude of SPF values.

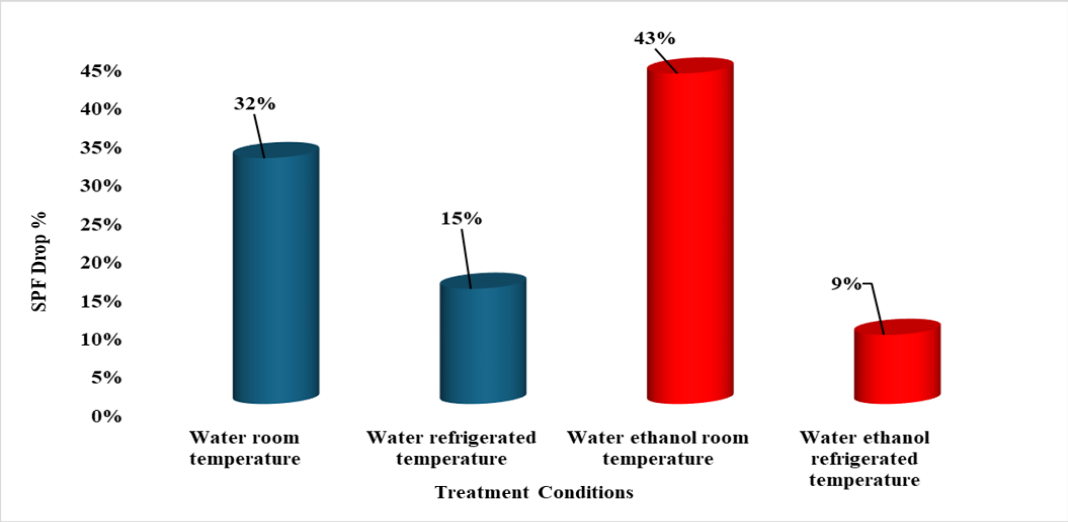

Fig. 5. SPF drop for 6 days for water (blue) vs. water-ethanol (red) at room temperature and refrigerated conditions.

Table 5. Pearson correlation coefficients (r) and their corresponding p-values for SPF vs. Days.

Condition	r (Pearson)	p-value	Significance
W. Room Temp.	−0.923	0.009	($p < 0.01$)
W. Refrigerated	−0.984	0.001	($p < 0.001$)
W.E. Room Temp.	−0.901	0.014	($p < 0.05$)
W.E. Refrigerated	−0.948	0.004	($p < 0.01$)

W. = Water; W.E. = Water-Ethanol mixture

Table 6. Pearson correlation results comparing SPF values between the two solvent types (water vs. water–ethanol).

Condition	r (Pearson)	p-value	Significance
Room Temp.	0.952	0.004	($p < 0.01$)
Refrigerated	0.968	0.002	($p < 0.01$)

4. CONCLUSIONS

This study demonstrated and confirmed that temperature, incubation period, and solvent used are important factors in how well *S. raeseri* maintains its SPF value over time. Specifically, the refrigerated conditions extend the extract shelf-life, likely because colder solvent prevents the rapid photodegradation of key phenolic compounds. The analysis of results also confirmed that the choice of solvent and incubation conditions (temperature) significantly affects the photoprotective potential of these herbal extracts. *S. raeseri* extracts exhibit greater photochemical stability and longer shelf-life at refrigerated conditions with higher SPF values for water solutions. The degradation was slower in a water-ethanol solvent. As an alternative to synthetic UV filters, the use of *S.raeseri* extracts could be recommended for the development of plant-based sun protective cosmetic formulations. This is particularly relevant for formulations seeking to minimize synthetic UV filters, given concerns about allergenicity and environmental pollution. Further studies are needed to evaluate the effect of pH and the half-life of the degradation of SPF in various solvents.

5. ACKNOWLEDGMENT

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6. CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding this publication.

7. ETHICAL STATEMENT

Not applicable. In this study, neither humans nor animals were involved, and no clinical trials were conducted.

8. FUNDING

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9. AUTHORSHIP CONTRIBUTION

Emil Xhuvani conceived, designed, drafted, and analysed the results. Kejda Kristo, Matilda Mema and Irdisa Hima performed the experimental measurement and data collection. All authors agreed to publish the final manuscript.

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