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*Original Article*

# SUN PROTECTION PROPERTIES AND PHOTOSTABILITY OF AQUEOUS EXTRACTS OF DANDELION (*TARAXACUM OFFICINALE L.*)

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**ABSTRACT**

The aim of this study was to determine the sun protection properties and photostability of aqueous extracts of *Taraxacum officinale L.* growing locally in the West Kazakhstan region. These properties were examined using UV-Vis spectroscopy, and the relevant metrics were calculated using the Mansur equation. Qualitative phytochemical screening revealed the presence of both primary and secondary metabolites in extracts obtained from the whole plant and its parts. The phenolic compounds present in extracts mainly contributed to the absorption of UV rays in the wavelength range of 280–400 nm. Six-week experiments allowed the detection of significant photostability of most of the extracts studied, up to 86.8% for leaf-derived extracts. It was observed that the first few days of exposure caused the greatest loss of sun protection properties of the extracts. It was also confirmed that the concentration of the extracts has a direct influence on the sun protection properties of the aqueous extracts from the roots, leaves, inflorescences, and the whole plant of *T. officinale*. The study found that the sun protection properties of *T. officinale* aqueous extracts are comparable to the same properties of dibenzalacetone, a synthetic ingredient commonly found in modern sunscreens. In addition, both the plant parts and the concentration of the extract were found to determine the tested extracts' photostability and sensitivity to direct sunlight.

**KEYWORDS:** sun protection factor, skin protection, plant extracts, photostability, *Taraxacum officinale L.*



## 1. Introduction

Using sunscreen is the most reliable and easiest way to protect human skin from UV radiation-induced photodamage. Cosmetic sunscreen products have been used for more than 75 years and are composed of substances that absorb or reflect UV radiation, thereby protecting human skin from direct sunlight [1]. For this purpose, sunscreens with high sun protection properties are the most preferred among users [2]. Plant compounds bearing aromatic rings and multiple bonds in functional groups usually exhibit broad absorption, covering a wavelength range of 200–400 nm. Natural products are, therefore, suitable as UV filters, and the addition of herbal ingredients in skin care cosmetics is a contemporary trend [3].

The sunscreen industry is expected to reach $10.7 billion in 2024, and *T. officinale* extracts are considered a cleaner, healthier, and more effective alternative to sunscreens because they are more natural and have a more beneficial effect on human skin [4]. Aqueous extracts of *T. officinale* have long been used in traditional medicine to treat various diseases. They have a significant ability to protect human skin fibroblasts from cellular ageing and are effective protectants against UVB rays [5]. *T. officinale* extracts have been shown to have great potential to inhibit tyrosinase activity and can also be used in the development of skin care cosmetics [6].

*T. officinale*, commonly known as dandelion, belongs to the *Asteraceae* family and is one of the medicinally important plants among the flora of Kazakhstan [7]. Numerous scientific studies have confirmed the pharmacological properties of *T. officinale* [8]. The extracts *of T. officinale* have anti-inflammatory, antioxidant, and anticarcinogenic traits. Many phytochemicals have been found and identified in the *Taraxacum* herb. However, there are only a few scientific studies investigating *T. officinale* extracts in the treatment of skin diseases [5]. Although the

phytochemistry of *T. officinale* is well known, its useful properties need to be further explored and propagated [9].

The use of *T. officinale* is based primarily on empirical findings. Numerous health-promoting properties of extracts from the whole plant of *T. officinale* and compounds extracted from its leaves or roots have been demonstrated in several studies [10]. In our previous work, we determined the phytochemical composition of *T. officinale* and demonstrated its significant antioxidant and antiradical activity [11]. However, there is still a dearth of studies proving the sunscreen properties of *T. officinale* growing locally in Western Kazakhstan. Therefore, in the present work, the sun protection properties and photostability of aqueous extracts of whole plants, inflorescences, leaves, and roots of *T. officinale* have been investigated.

## 2. Materials and methods

### 2.1. Reagents

All reagents are of analytical grade, purchased from commercial suppliers, and used without further purification. Double distilled water with a residual conductivity of 1.23 ± 0.22 mg/dm$^3$ (NaCl) was used for extraction and reagent preparation.

### 2.2. Collection and identification of plant material.

The plants were collected during the flowering phase in summer in their natural habitat, away from roads and industrial enterprises. The plants were identified in the herbarium of the Faculty of Natural Geography of the M. Utemisov West Kazakhstan University and in a "Worldfloraonline" Internet source [12]. The dust and sand on the plants were thoroughly washed with tap water before rinsing them 2-3 times with double distilled water. Subsequently, they were kept in a shaded ambient atmosphere for two weeks until they were completely dry. The dried samples were then ground into a fine powder, which was stored at 4°C and used for extraction.

### 2.3. Extract preparation.

To prepare the extracts, 10 g of dried, powdered plant sample was transferred to a 250 mL Erlenmeyer flask and extracted 3 times x 100 mL with double distilled water for 4 hours at 60°C. The combined extracts were evaporated, and the solid residue was dried at 50°C to constant weight. The obtained extracts were stored at 4°C and used for phytochemical analysis and SPF determination.

### 2.4. Determination of the sun protection factor (SPF).

To determine the SPF, the dried extracts were dissolved in pure ethanol to obtain concentrations of 0.1, 0.25, 0.5, 0.75, and 1.0 mg/mL. The absorption spectra were recorded with an SF-56 spectrophotometer in the UVB region (290 to 320 nm), with intervals of 5 nm, in a 1.0 cm quartz cuvette against pure solvent as a blank sample. The SPF values were calculated using the Mansur equation [13] as follows:

$$SPF = CF \sum_{290}^{320} EE(\lambda) \times I(\lambda) \times abs(\lambda) \qquad (1)$$

where:

EE (λ) is the erythemal effect spectrum,
I (λ) is the solar intensity spectrum,
abs (λ) is the absorbance,
CF is the correction factor (10).

The values of EE x I are constants determined by Sayre *et al.* [14] and listed in Table 1.

**Table 1.** Normalized product function used in the calculation of SPF

| Wavelength (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 |
| Total | 1.0000 |

***EE:** erythemal effect spectrum

**I:** solar intensity spectrum

### 2.5. Determination of photostability.

To investigate the photostability of the aqueous extracts of *T. officinale*, the extract solutions of all concentrations were divided into two sets and stored parallelly in sunlight and in the dark for 6 weeks at room temperature. During the first week of exposure, the sun protection factor of the extracts was redetermined daily and then only once a week.

The photostability of tested extracts was calculated with the following equation:

$$\text{Photostability (\%)} = \frac{SPF}{SPF_0} \times 100 \qquad (2)$$

where $SPF_0$ is the sun protection factor of freshly prepared extract, and SPF is the sun protection factor of extract after 6 weeks of exposition.

Each measurement was carried out in triplicate, and data were presented as the average of three independent determinations ± standard deviation with a confidence probability (α) of 0.95.

### 2.6. Qualitative phytochemical screening.

The obtained aqueous extracts of *T. officinale* were subjected to qualitative phytochemical tests using standard techniques [15,16]. The presence of primary and secondary metabolites was determined as follows:

***Carbohydrates (Molish's test)***. Two drops of a freshly prepared 20% alcohol solution of α-naphthol were added to 1 mL of the sample, and the mixture was shaken well. Then 1 mL of concentrated $H_2SO_4$ was carefully added down the side of the test tube to form a layer. The appearance of the purple ring indicates the presence of carbohydrates.

***Reducing sugars (Benedict's test)***. To 1 mL of aqueous extract, 2 mL of Benedict's reagent [17] was added. After heating on a boiling water bath for a few minutes, a red

precipitate appears, indicating the presence of reducing sugars.

***Starch (iodine test)***. A 1 mL of extract was added to 4-5 mL of distilled water, followed by the addition of a few drops of aqueous $I_2$/KI solution. A blue color indicates the presence of starch.

***Proteins (Biuret test)***. *To* 2 mL of the analyzed alcoholic extract, 2-3 drops of 2% $CuSO_4$ solution were added, followed by an excess addition of KOH (in pellets). The appearance of a pink color indicates the presence of proteins.

***Amino acids***. A few drops of a freshly prepared 0.2% acetone solution of ninhydrin were added to 1 mL of the extract. The appearance of a purple color confirms that the test as positive.

***Gums***. 2 mL of alcoholic extract was poured into 5 mL of distilled water. Then the solution was shaken well. The appearance of swells, adhesives, or precipitate indicates the presence of gum.

***Carboxylic acids***. A pinch of solid $NaHCO_3$ was added to 1-2 mL of extract. Gas evolution indicates the presence of acids.

***Alkaloids (Dragendrof's test)***. To 2-3 mL of the extract dissolved in water, 1 mL of Dragendrof's reagent was added. An orange or red precipitate indicates that alkaloids are present.

***Test for phenolic compounds***. A few drops of a neutral 5% ferric chloride solution were added to 2-3 mL of aqueous extract. The formation of a dark green color indicates the presence of phenolic compounds.

***Flavonoids (Shinoda's test)***. To 1 mL of alcoholic extract a few turns of magnesium and a few drops of concentrated HCl were added. The appearance of a red color was taken as evidence of the presence of flavonoids.

***Phlobatannins***. Aqueous extract (2 mL) was boiled with an equal volume of 1% HCl, resulting in the deposition of a reddish precipitate indicating the presence of phlobatannins.

**Saponins (frothing test).** 1 mL of alcohol extract was shaken vigorously with 5 mL of distilled water in a test tube for 30 seconds. The formation of a stable froth that persisted for 10-15 minutes confirms the presence of saponins. If a few drops of olive oil are added to the foam and shaken vigorously, the formation of an emulsion can be observed.

***Steroids***. To 2 mL of extract, 2 mL of $CHCl_3$ and 2 mL of concentrated $H_2SO_4$ were added. The presence of steroids is indicated by a red color and yellowish-green fluorescence.

***Xanthoproteins***. A few drops of nitric acid and ammonium hydroxide were added to 1 mL of extract. A reddish-brown precipitate indicates the presence of xanthoproteins.

***Anthocyanins***. 2 mol/L of HCl solution was added to 2 mL of aqueous extract, followed by the addition of ammonium hydroxide. The conversion of pink-red to blue-violet indicates the presence of anthocyanins.

***Leucoanthocyanins***. 5 mL of *iso*-amyl alcohol were added to 5 mL of extract dissolved in water. The red appearance of the upper (alcohol) layer indicates the presence of leucoanthocyanins.

## 3. Results and discussion.

### 3.1. Qualitative phytochemical screening

Table 2 presents the results of qualitative phytochemical tests of *T. officinale* aqueous extracts.

**Table 2.** Qualitative phytochemical screening of *T. officinale L.* aqueous extracts

| Phytocomponent | Whole plant | Inflorescences | Leaves | Roots |
|---|---|---|---|---|
| **Primary metabolites** | | | | |
| Carbohydrates | + | + + | - | + |
| Reducing sugars | + + | - | + | + + |
| Starch | - | - | - | - |
| Proteins | + | + + | + + | - |
| Amino acids | + | + | + | - |
| Gum | + | + + | + | + + |
| Carboxylic acids | + | + + | + | - |
| **Secondary metabolites** | | | | |
| Alkaloids | + | + | - | + |
| Phenols | + + + | + + | + + + | + |
| Flavonoids | + | + | - | + + |
| Phlobatannins | + | - | + | - |
| Saponins | + | + + | + | + + |
| Steroids | - | - | - | - |
| Xanthoproteins | + | + + | + | + |
| Anthocyanins | + | + | + | - |
| Leucoanthocyanins | + | + + | + | - |

*(+++) - highly present, (++) - moderately present, (+) - lowly present, (-) - absence.*

Phytochemical screening revealed the presence of both primary and secondary metabolites in the tested extracts. Phenols, gums, and saponins have been found in all parts of the plant and are accordingly present in significant quantities in extracts of the whole plant. Carbohydrates were detected in inflorescences and roots, and reducing sugars were found in leaves and roots. Proteins, amino acids, and carboxylic acids were detected in leaves, inflorescences, and the whole plant. Dragendorf's test was used to detect the presence of alkaloids in roots, inflorescences and the whole plant. A positive result of the Shinoda test for flavonoids was observed for inflorescences, roots, and whole plants. Phlobatannins have been detected in whole plants and leaves. Anthocyanins and leucoanthocyanins were detected in leaves, inflorescences, and the whole plant. However, starch and steroids were not detected by standard tests.

### 3.2 UV-Vis absorption analysis.

For UV-Vis-spectroscopy analysis, the extracts were diluted in ethanol and then filtered. The obtained solutions were scanned at wavelengths from 275 to 700 nm to

estimate the UV-Vis profile of studied extracts. The UV-Vis spectra of *T. officinale* aqueous extracts are shown in Figure 1.

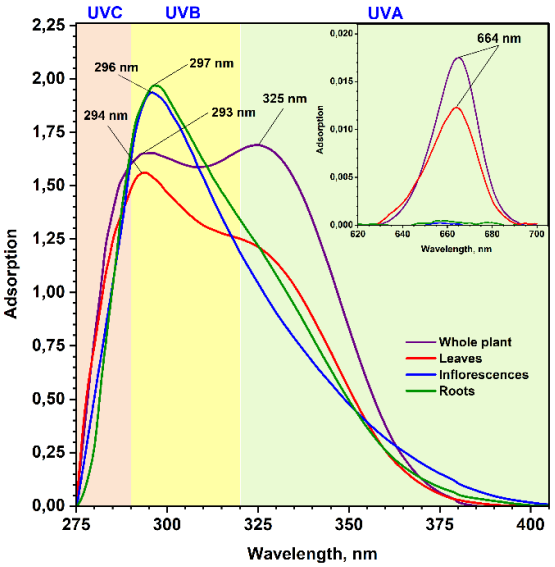


**Figure 1.** UV-*Vis*-spectra of *T. officinale* aqueous extracts (solution in ethanol)

The UV-Vis profile from Figure 1 shows that the UV absorption capacity of aqueous *T. officinale* extracts is significant, predominantly in the UVB (290–320 nm) and UVA ranges (320–400 nm). The absorption spectra show that the compounds contained in the extracts have a great ability to absorb UV radiation, and the resulting extracts can therefore be used as potentially effective skin protection agents [18]. Peak values ($\lambda_{max}$, nm) are demonstrated in Table 3.

**Table 3.** UV-Vis peak values of *T. officinale* aqueous extracts (solution in ethanol).

| Plant part | $\lambda_{max}$, nm | Abs | Phytocomponent |
|---|---|---|---|
| Whole plant | 293 | 1.6522 | Phenolic compounds |
| | 325 | 1.6915 | Phenolic compounds |
| | 664 | 0.0174 | Chlorophyll A |
| Inflorescence | 296 | 2.5979 | Phenolic compounds |
| Leaves | 294 | 1.5638 | Phenolic compounds |
| | 664 | 0.0123 | Chlorophyll A |
| Roots | 297 | 1.9673 | Phenolic compounds |

The large baseline with peaks at 294–298 nm in all extracts corresponds to aromatic rings of phenolic phytocomponents, which generally have absorption peaks in the UV range of 250–350 nm [19]. The maximum absorption at 325 nm in the spectra of whole plants and shoulders in the same region in the spectra of aqueous extracts of leaves and roots could be due to π-π* transitions since polyphenolic compounds are present in the tested extracts [20]. The absorption band in the red region with the maximum at 664 nm corresponds to chlorophyll A (Figure 1, insert) [21]. The extract of leaves, as well as the extract of the whole plant, contains chlorophyll A, the green pigment responsible for photosynthesis.

### 3.3. Sun protection factor and photostability determination

The absorption values determined from UV-Vis-spectra were used to calculate the sun protection factor according to Equation (1). Figure 2 shows the sun protection factor of freshly prepared ethanolic solutions of *T. officinale* aqueous extracts as well as the sun protection factor of these extracts after 6 weeks of exposure to direct sunlight and in the dark.

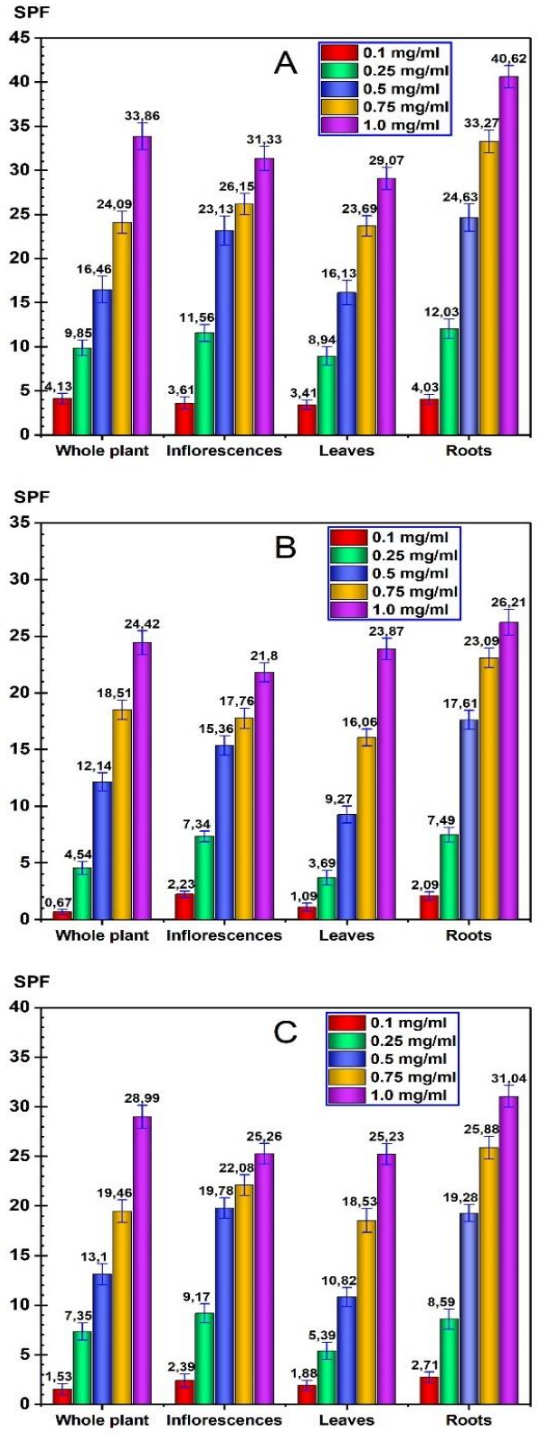


**Figure 2.** Sun protection factor (SPF) of freshly prepared ethanolic solutions of *T. officinale L.* aqueous extracts (A), after 6 weeks of exposure in direct sunlight (B) and after 6 weeks of exposure in the dark (C) at different concentrations.

As can be seen, freshly prepared solutions of *T. officinale* aqueous extracts show significant sun protection capacity in the UVB range, which depends on the concentration (Figure 2A). The corresponding SPF values ranged from 3.41 (leaves, 0.1 mg/mL) to 40.60 (roots, 1.0 mg/mL). Therefore, a higher extract concentration offers better protective performance. At high concentrations, the sun protection factor of whole plant extracts corresponds to approximately an average of the sun protection factor values of the plant parts. Regarding the UVB range, extracts from roots showed the highest ability to absorb UV light. However, leaf extracts had the lowest but significant UV absorption capacity, up to 29.07, at a maximum concentration of 1.0 mg/mL.

Figures 2B and 2C show a decrease in sunscreen activity of the studied extracts when stored in sunlight and in the dark, respectively. It is clear that different storage conditions of extracts significantly impact the change in their sun protection properties over time.

The dynamics of changes in the sun protection properties of the studied extracts over 6 weeks of the experiment are shown in Figure 3.

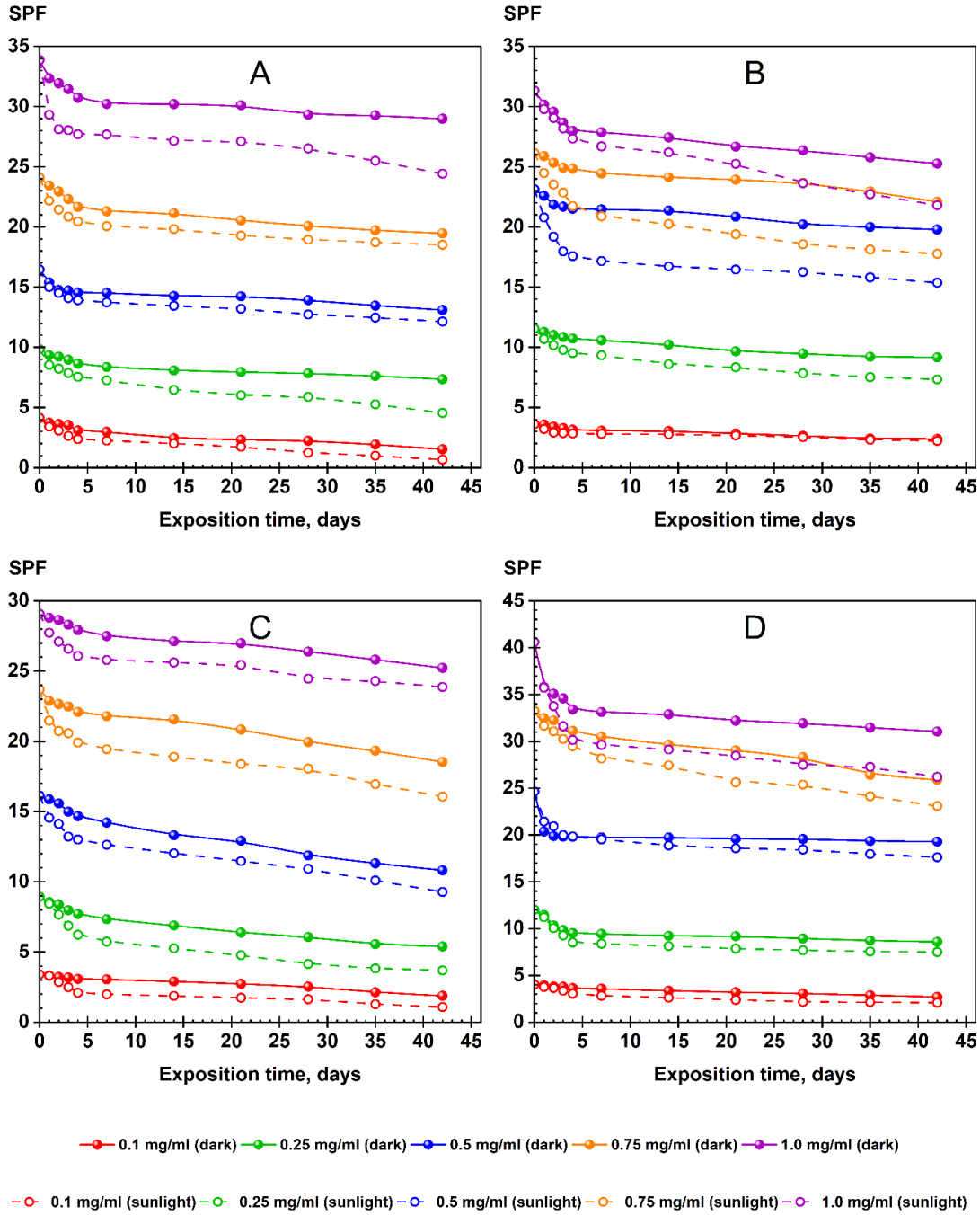


**Figure 3.** Change of sun protection factor (SPF) of *T. officinale* aqueous extracts during 6 weeks of exposure to sunlight and in the dark: A – whole plant, B – inflorescences, C – leaves, D – roots.

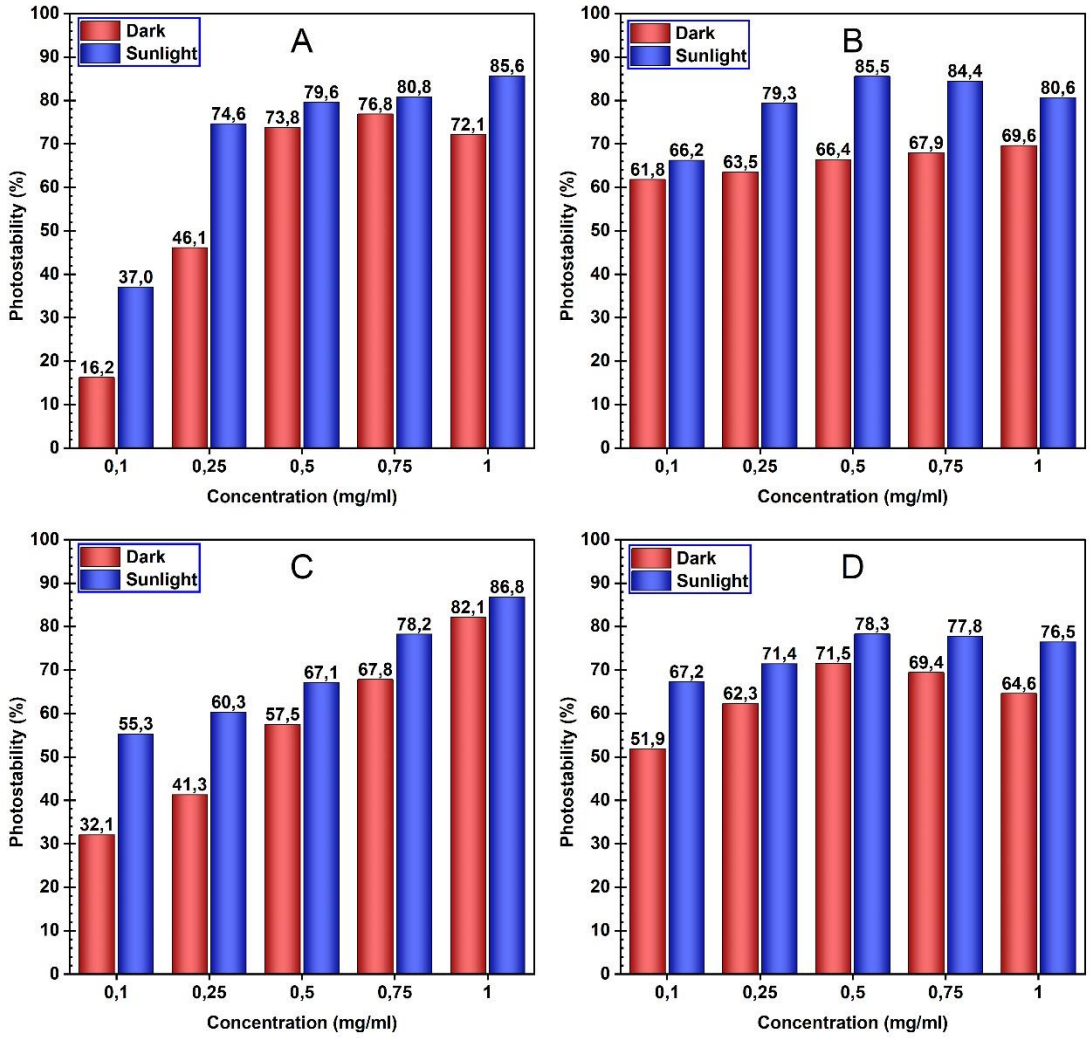


**Figure 4.** Photostability of *T. officinale* aqueous extracts after 6 weeks of exposure in direct sunlight and in the dark at different concentrations: A – whole plant, B – inflorescences, C – leaves, D – roots.

Figure 3 shows that the SPF values of all extracts gradually decrease over time. The most significant decrease in UV light absorption in the UVB range was observed for all extracts in the first 5–7 days of exposure to both dark and direct sunlight. As can be seen, the extracts exhibit the greatest stability when stored in the dark, while their stability is slightly lower when stored in sunlight. The data obtained are consistent with previous studies showing that plant extracts enriched with flavonoids have better stability and maintain their SPF when stored in the dark compared to those exposed to sunlight [22]. At the same time, exposure to sunlight can accelerate the breakdown of antioxidant compounds in plant extracts, reducing their effectiveness in protecting against UV radiation. This degradation is barely visible when stored in the dark [23].

The photostability percentage of the aqueous extracts of *T. officinale* was calculated using Equation (2). The results obtained are shown in Figure 4.

Figure 4 shows that the photostability of the studied extracts ranged from 16.2% for whole plants at 0.1 mg/ml exposed to sunlight to 86.8% for leaf extracts at 1.0 mg/ml stored in the dark. The photostability of the tested extracts directly depends on their concentration. Nevertheless, it was found that extracts from inflorescences and roots of *T. officinale* become less photostable at excessive concentrations of more than 0.5 mg/mL. This deterioration in sun protection properties can be attributed to photodegradation or the saturation effect. In the first case, an increased concentration of plant extracts leads to a higher photodegradation rate of the active ingredients when exposed to UV light and thereby reduces their sun protection effect [24]. On the other hand, there may be a saturation point beyond which additional extract does not significantly increase UV absorption. This also leads to a reduction in sun protection efficiency [25].

The difference in photostability (ΔPS) of the examined extracts when stored in sunlight and in the dark was evaluated as follows (3):

$$\Delta PS\ (\%) = PS_{dark} - PS_{sunlight} \quad (3)$$

This difference allows for an evaluation of the extract's relative sensitivity to sunlight. Results are presented in Figure 5.

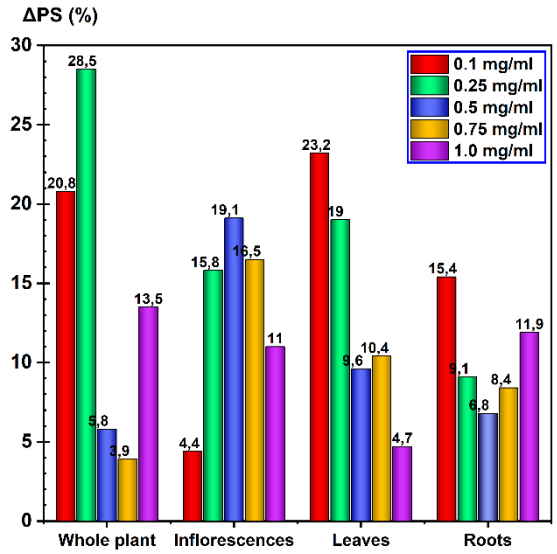


**Figure 5.** The difference in photostability (ΔPS) of *T. officinale* aqueous extracts after 6 weeks of exposure to direct sunlight and in the dark at different concentrations.

Figure 5 clearly shows that the difference in photostability of *T. officinale* aqueous extracts in sunlight and in the dark becomes less significant with increased extract concentration. In most cases, the difference in photostability for dilute extract solutions is quite large and can exceed up to 20%. The difference in photostability of the tested extracts is between 3.9% (whole plant, 0.75 mg/mL) and 28.5% (whole plant, 0.25 mg/mL), which indicates that the aqueous extract of *T. officinale* whole plant, at a concentration of 0.75 mg/mL, is the least sensitive to direct sunlight.

Obtained results allow the most effective extracts to be distinguished based on their overall properties (SPF, photostability, sensitivity to sunlight). Table 4 summarises the most effective extracts.

**Table 4.** The most effective and photostable *T. officinale* aqueous extracts.

| Plant part | Concentration, mg/mL | SPF | PS% | ΔPS |
|---|---|---|---|---|
| **Leaves** | 1.0 | 29.07 | 86.8 | 4.7 |
| **Whole plant** | 0.75 | 19.46 | 80.8 | 3.9 |
| **Roots** | 0.5 | 24.63 | 78.3 | 6.8 |

The sun protection effect of the tested extracts is comparable to commercially available substances used in modern sun protection/screen products. Dibenzalacetone is a synthetic ingredient used in sunscreens with an SPF of 39.98. This compound is quite stable and maintains its absorbency under UVB radiation over a wide pH and temperature range for a long period of time [26]. A comparison of the SPF value of dibenzalacetone with the examined aqueous *T. officinale* extract shows that the SPF of freshly prepared ethanolic solutions of the extracts is very close to that of dibenzalacetone. Due to the presence of phenols and flavonoids, aqueous extracts of *T. officinale* can be used as non-toxic and environmentally friendly components of sunscreens to protect human skin from UVB radiation.

## 4. Conclusion

The main goal of the current study was to estimate the ability of *T. officinale* aqueous extracts to absorb UV rays in the UVB range. The investigation showed that aqueous extracts obtained from *T. officinale* roots, leaves, inflorescences, and the whole plant have a great ability to absorb UVB radiation. The high absorption capacity of the tested extracts is primarily due to the presence of phenolic compounds. Most extracts exhibit significant photostability of up to 80% from their original sun protection activity. However, studies have shown that extracts stored in the dark retain their UV-light absorption capacity more effectively than those exposed to direct sunlight. Therefore, the significant UVB-absorption ability comparable to synthetic components of sunscreens and high photostability suggests that *T. officinale* growing in Western Kazakhstan has substantial prospects for practical application in protecting human skin from harmful solar radiation.

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