Mineral Water as a Sustainable Raw Material for Skincare Products and Protective Natural Antioxidant from Solar Irradiation: Stability of Vitamin C and In Vitro Antioxidant Assessments

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Abstract: Oxygen is crucial for life, but its reactive species, like free radicals, can damage health and accelerate aging. Antioxidants from natural and synthetic sources mitigate these effects. Kanjiža Spa’s mineral-rich thermal water is renowned for its therapeutic benefits and potential in eco-friendly pharmaceuticals and cosmetics. Hence, the utilization of mineral water in pharmaceutical and cosmetic applications when exposed to artificially generated free radicals under simulated solar irradiation and different experimental conditions (pH values and mineral concentrations in the thermal water) was researched. Three different dermocosmetic products designed with raw minerals and water from Kanjiža Spa were tested. Our findings confirmed the protective effect of mineral water, as evidenced by the higher stability of vitamin C in thermal water. The degradation of vitamin C was significantly reduced in the presence of mineral water, with the least degradation occurring at pH = 7, which closely matches human skin pH. These results were further validated using 2,2-diphenyl-1-picrylhydrazyl and ABTS tests. Overall, the obtained results underscore the therapeutic and commercial potential of Kanjiža Spa’s mineral water, suggesting that it could be a valuable ingredient in next-generation skincare and pharmaceutical products.

Keywords: mineral water; sustainability; pharmaceuticals; cosmetics; stability; photodegradation; vitamin C; antioxidative activity

1. Introduction

Oxygen is vital for life but can also exhibit destructive properties through the production of reactive oxygen species [1]. Paradoxically, oxygen can also exhibit destructive properties with oxidative species, posing a threat to living organisms [2]. For instance, when mitochondria degrade adenosine triphosphate, they produce free radicals, which may have potentially harmful roles [1]. Additionally, environmental factors like UV light from solar irradiation can induce the formation of reactive oxygen species [3]. While low levels of these species can bolster the immune system, elevated levels lead to oxidative stress and contribute to the development of various diseases. Such cellular damage contributes to the development of various serious ailments including cancer, arthritis, aging, autoimmune disorders, and cardiovascular and neurodegenerative diseases [1]. Considering the above,
it is evident that eliminating (or inactivating) these harmful substances from physiology is essential for maintaining organisms’ health.

Antioxidants, from both natural and synthetic sources, are compounds capable of mitigating the oxidation of proteins, carbohydrates, lipids, and deoxyribonucleic acid. Natural sources, such as fruits and vegetables, are commonly rich in antioxidants, while synthetic sources predominantly include pharmaceutical drugs manufactured by various pharmaceutical and cosmetic industries [4].

Unfortunately, pharmaceutical and cosmetic factories discharge significant volumes of wastewater into natural ecosystems during production, leading to the presence of diverse active pharmaceutical ingredients (APIs) in the environment that may include artificial antioxidants from drugs [5]. These APIs can induce unforeseen effects on non-target organisms. Consequently, reducing the amounts of released polluted water and implementing proper remediation treatments before it enters ecosystems is essential for the environment [6–8], as well as replacing the synthetic antioxidants in designed products with those that are not toxic to the environment when released after manufacturing.

Accordingly, significant attention is directed towards environmentally problematic personal care products that are present in aquatic environments at high concentrations. Notably, various UV filters have been identified in a range of water samples, particularly during summer months, as they are washed away from the skin into waterways during outdoor activities [9]. Commonly applied anti-UV skin products present certain issues for the environment and humans alike. For instance: (i) environmental impact—UV filters, especially those like oxybenzone and octinoxate, have harmful effects on marine life, particularly coral reefs [10]. (ii) Limited UV range—some UV filters only protect skin against certain wavelengths of UV radiation. This means that cosmetic products containing only one type of UV filter may not provide a broad spectrum of skin protection [11]. (iii) Stability—some UV filters degrade when exposed to sunlight, which reduces their effectiveness over time. For instance, this may mean that sunscreen needs to be reapplied more frequently [11]. (iv) White skin cast—certain UV filters, particularly physical blockers like zinc oxide and titanium dioxide, can leave a white cast on the skin, making it less aesthetically pleasing, especially on darker skin tones [11]. These issues have to be addressed adequately in order to design functional, effective, but also eco-friendly cosmetic products [11].

Given the aforementioned concerns, there is a pressing need to discover or develop antioxidants that are both eco-friendly and effective for human skin protection and care. The application of selected natural raw materials as main ingredients, such as mineral water from Kanjiža Spa, could improve the efficiency of personal care products but also ensures that they are ecofriendly. Fortunately, Serbia and the Autonomous Province of Vojvodina, situated within the Pannonia Basin, boast abundant reserves of thermal mineral waters. These waters, often utilized in balneology, exhibit exceptional geothermal properties surpassing European hydrogeological standards. Consequently, Vojvodina’s thermal mineral waters hold significant potential for medical applications [12].

Vitamin C, also known as ascorbic acid, is a compound comprised of six carbons and shares a relation with the C6 sugars. Serving as a crucial micronutrient, it plays a pivotal role in sustaining normal metabolic functions and bodily equilibrium. Particularly so, as it is strongly associated with maintaining healthy skin via collagen synthesis. Mammalian cells lack the ability to produce ascorbic acid independently due to the absence of the essential enzyme L-gulono-1,4 lactone oxidase. Natural sources of vitamin C predominantly include vegetables and fruits, although only a select few plants are abundant in this nutrient. Presently, industrial production of ascorbic acid relies on D-glucose, involving a series of intricate chemical and biotechnological processes. The primary obstacle in creating ascorbic acid products lies in its susceptibility to instability and reactivity. Ascorbic acid is a crucial antioxidant for skin health, but it is susceptible to photodegradation, which can be influenced by factors like the pH and mineral content. Ascorbic acid acts as a scavenger for free radicals and other oxygen species, shielding cells from oxidative harm induced by reactive oxygen species [13]. Hence, it is a very important molecule that is
easily obtained from nature and is a useful indicator of degradation rates under (simulated) solar irradiation while being vital for cosmetic skin products as natural raw material due to collagen synthesis.

Photolytic degradation in laboratory settings is a good source of (simulated) usual solar irradiation. For instance, photolytic degradation (e.g., simulated solar irradiation) of vitamin C has already been widely examined for different purposes. For instance, Neto et al. [14] investigated the photostability of vitamin C in products containing it, aiming to assess the protective capabilities of packaging against vitamin C photodegradation. The findings indicated that after photostability tests conducted with fruit juices and jellies packaged in both polyethylene terephthalate and glass bottles or flasks, L-ascorbic acid was undetectable, suggesting that the packaging failed to offer effective protection against vitamin C photodegradation. Noreen et al. [15] examined the photoxidation of ascorbic acid sensitized by riboflavin across a pH range of 2.0 to 12.0, under ambient air and anaerobic conditions, employing UV and visible irradiation sources. The degradation kinetics of ascorbyl anion in aqueous solutions, in the presence of riboflavin, followed first-order kinetics for its photodegradation. As the pH increases, there is a corresponding rise in the ionization of the ascorbyl anion and the redox potential, resulting in higher rates of photodegradation of the ascorbyl anion.

Since no similar data were previously reported, the study aimed to test the ability of Kanjiža Spa mineral water to protect vitamin C from photodegradation and formulate eco-friendly personal care products. In that sense, the protective effect of mineral water was tested as an agent against the degradation of L-ascorbic acid (vitamin C), which is model compound due to its importance for skin health and photosensitivity under simulated solar irradiation. Samples with ultrapure and mineral water, as well as with concentrate (obtained by evaporating different volumes of mineral water), were exposed to simulated solar irradiation. Additionally, the influence of the initial pH and mineral concentration of thermal water on the photodegradation rate of vitamin C were also tested to obtain the optimal conditions for personal care product manufacturing while preserving mineral water efficiency. The investigated mineral water was characterized for its potential antioxidative activity using three different spectrophotometric assays. Finally, after examining the water samples, dermocosmetic preparations/products (micellar water, moisturizing serum and moisturizing cream) based on mineral water as an active substance and natural raw material were formulated.

2. Materials and Methods

2.1. Reagents and Chemicals

The mineral water samples were collected from Kanjiža Spa (Kanjiža, Vojvodina, Serbia) in November 2022. The mineral water was kept in a refrigerator and was used without further treatment, except the experiments with various mineral concentrations, when 30%, 50%, and 70% of the water samples was evaporated in order to concentrate the present elements.

For the investigation of the possible stability-enhancing effect of mineral water, a 0.05 mM solution of vitamin C (Avena Lab—Farmadria d.o.o., Vršac, Serbia) was freshly prepared prior to photodegradation experiments, dissolving an appropriate amount of vitamin C in ultrapure and mineral water.

The initial pH values were set using 0.1 M HClO4 (70% (w/w), >99.99%, Sigma-Aldrich, St. Louis, MO, USA) and 0.1 M NaOH (pro analysi, MOSS & HeMOSS, Belgrade, Republic of Serbia).

To determine the protective efficiency of mineral water, the samples taken after photodegradation were analyzed using liquid chromatography with the following components of mobile phase: acetonitrile (99.9%, Sigma-Aldrich, St. Louis, MO, USA) and orthophosphoric acid (85%, pro analyti, Sigma-Aldrich, St. Louis, MO, USA).

For the antioxidant activity determination, 1,1-diphenyl-2-picryl-hydrazyl-hydrate (DPPH), 2,2'-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt (ABTS),
iron (III)-chloride, potassium hexacyanoferrate (III), sodium hydrogen phosphate anhydrous, sodium dihydrogen phosphate and trichloroacetic acid were purchased from Sigma (Sigma-Aldrich GmbH, Steinheim, Germany).

For the preparation of dermocosmetic products, the following substances were used:
(i) Micellar water formulation (ingredients listed according to INCI nomenclature): water, glycerol, glucose, polysorbate 20, fructose, citric acid, peg-7 glyceryl cocoate, coco glucoside, phenoxethanol, and lactic acid (Avena Lab—Farmadria d.o.o., Vršac, Serbia).
(ii) Serum formulation (ingredients listed according to INCI nomenclature, with letters denoting the corresponding phase of the preparation): propylene glycol, methyl gluceth 10, sodium L-pyroglutamate, sorbitol, polysorbate 20, phenoxyethanol, citric acid, and hyaluronic acid (Avena Lab—Farmadria d.o.o., Vršac, Serbia).
(iii) Cream formulation (ingredients listed according to INCI nomenclature, with letters denoting the corresponding phase of the preparation): water, C12-15 alkyl benzoate, glycerol monostearate (se), caprylic/capric triglyceride, ceteareth-20, polysorbate 20, tapioca starch, sodium acrylates copolymer, squalane, urea, coco-caprylate/caprate, dimethicone, propylene glycol, cetyl diglyceryl tris(trimethylsiloxy)silyl ethyl dimethicone, phenoxyethanol, sodium ascorbyl phosphate, tocopherol, and citric acid (Avena Lab—Farmadria d.o.o., Vršac, Serbia).

2.2. Sample Preparation and Analytical Procedures

The photodegradation experiments were conducted using a TOPT-V photoreactor from Toption instrument Co., Ltd, Xi’an, Shaanxi, China. The samples were prepared and irradiated in quartz glass photochemical cells, each with a total volume of approximately 100 mL. These cells were arranged in a circular formation around a 300 W xenon (Xe) lamp from Toption, which served as the source of simulated solar irradiation (SSI). To ensure uniform exposure to the irradiation source, the cells were equally spaced. The xenon lamp was housed within a quartz cold trap equipped with water-circulating jackets and connected to a cooler, maintaining a constant temperature within the photoreactor (Figure 1).

Samples of vitamin C, collected at different irradiation intervals (5, 10, 15, and 30 min) using SSI, were first filtered through Millipore (Millex-GV, Burlington, MA, USA, 0.22 µm) membrane filters to eliminate any impurities. Subsequently, the samples were analyzed with a high-pressure liquid chromatograph equipped with a diode array detector (UFLC-DAD, Shimadzu Nexera, Tokyo, Japan) set to detect at the vitamin C absorption maximum.
wavelength of 243 nm. Chromatographic separation was performed using an Inertsil® ODS-4 column (2.1 mm × 50 mm i.d., particle size 2 µm) maintained at 30 ºC. Prepared samples (20 µL) were injected for analysis. The mobile phase, delivered at a flow rate of 1.0 mL/min, consisted of a 50:50 (v/v) mixture of acetonitrile and water, with the water acidified to pH 2.56 using phosphoric acid, ensuring a phosphoric acid mass fraction of 0.1%. The reproducibility of repeated runs was around 3–10%.

Cation and anion determination in mineral water samples was previously conducted at the Institute for Rehabilitation in Belgrade, Department of Balneoclimatology (document number 43/1, 9 March 2016; document number 2/13, 25 January 2013). The following methods were used for the abovementioned analysis: SRPS EN ISO 10304:2009 ion chromatography; SRPS EN ISO 9963-1:2007 volumetry; APHA 4500-P E spectrophotometry with potassium antimonyl tartrate; SRPS H.Z1. 184:1974 spectrophotometry with Nessler’s reagent; APHA 3500-Ca D complexometric titration; APHA 3500-Mg E complexometric titration; EPA 200.7 ICP/OES; SRPS ISO 9964-3 flame photometry; and UP-543 spectrophotometry with Eriochrome Cyanine R.

pH values were monitored using a combined glass electrode (pH-Electrode SenTix 20, WTW, Thermo Fisher Scientific, Waltham, MA, USA) connected to a pH meter (pH/Cond 340i, WTW).

2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity of mineral water was determined using a simple and fast spectrophotometric method previously described elsewhere [16] with some modifications. Different sample volumes were mixed with 95% methanol (3 mL in total) and 1 mL 90 µM DPPH solution. After the 60 min incubation period in the dark at room temperature, the absorbance was measured at 517 nm. Radical scavenging capacity (RSC (%)) was calculated according to Equation (1).

\[
%\text{RSC} = 100 - \frac{A_{\text{sample}} \times 100}{A_{\text{control}}}
\]  

where A_sample is the absorbance of the sample solution and A_control is the absorbance of the control. All experiments were performed in three replicates. Antioxidant activity was expressed as an IC_{50} value, which represents the concentration of mineral water solution required to obtain 50% of the radical scavenging capacity.

ABTS•+ radical scavenging activity was determined according to the method described in the study by Vidović et al. [17] with some modifications. For the sample analysis, the ABTS•++ solution (stable for 2 days) was diluted with 5 mM/L phosphate-buffered saline (pH 7.4) to an absorbance at 730 nm of 0.70 ± 0.02. An aliquot (0.01 mL) of each sample was mixed with 4 mL of diluted ABTS•++ solution, and the decrease in absorbance was measured at 734 nm after 30 min at 30 ºC. The blank was prepared using distilled water. ABTS•+ radical scavenging activity of the mineral water was expressed as IC_{50} values (mg/mL).

The ferric ion reducing antioxidant power (FRAP) of mineral water was determined using a method previously described in the literature [18] with some modifications. Absorbance was measured at 700 nm. Antioxidant activity was expressed as an IC_{50} value (mg/mL). All experiments were performed in triplicate.

The Adrona water purification system was used to obtain ultrapure water.

After testing the water samples, and through experimental work (Figure 2) in a pharmaceutical–technological laboratory at the Faculty of Pharmacy Novi Sad, three dermocosmetic formulations were produced: micellar water, hydrating serum, and hydrating cream.

Mineral water for the production of dermocosmetic products was sterilized using the heating method according to the official method listed in Pharmacopoeia Jugoslavica IV. After cooling, it was filtered through coarse filter paper and adjusted to pH 7 using lactic acid.

Preparation of the micellar water: all individual ingredients were mixed in a laboratory beaker to obtain a homogeneous preparation, then filtered through laboratory filter paper and finally the product was packed in glass containers and sealed.
Preparation of the serum: water, sodium L-pyroglutamate, sorbitol, phenoxyethanol and citric acid were mixed to obtain a homogeneous solution. A suspension was prepared using propylene glycol, methyl gluceth 10, polysorbate 20 and hyaluronic acid. Portions of the suspension were added to the solution and mixed to hydration and homogenization using a D-160 Handheld Homogenizer (DLAB Scientific Co., Ltd., Beijing, China). The clear final product was packed into glass bottles with droppers and sealed.

Preparation of the cream: the following ingredients (phase A) were mixed to homogeneity: water, polysorbate 20, urea, and propylene glycol. Phase A was then heated in a water bath (HH-S8 water bath, Colo lab experts, Novo mesto, Slovenia) to 65 °C. Ingredients of phase B (C12-15 alkyl benzoate, glycerol monostearate (se), caprylic/capric triglyceride, ceteareth-20, sodium acrylates copolymer, squalane, coco-caprylate/caprate, cetyl diglycerol tris(trimethysiloxy)silylethyl dimethicone) were mixed to homogeneity and heated in a water bath to 70 °C. Portions of phase B were added to phase A and mixed with an HS-D Overhead Stirrer (Witeg Laboretechnik GmbH, Wertheim, Germany) until homogenization. Phase C was prepared by measuring the following substances in a laboratory beaker and mixed to homogeneity: tapioca starch, dimethicone, and tocopherol. The same procedure was applied for phase D (phenoxyethanol, sodium ascorbyl phosphate, and citric acid). After cooling phases A and B to 40 °C, phase D was added, followed by phase C. Homogenization continued until the mixture reached room temperature. Finally, the cream was packed into glass jars and sealed.

3. Results and Discussion

3.1. Stability Study of Vitamin C

Initially, the degradation of vitamin C was examined in ultrapure water across varying initial pH levels of 10 and 7, employing SSI. Analysis of the findings, as depicted in Figure 3, reveals that greater degradation occurs under alkaline conditions.

Namely, in the initial period of degradation, after 10 min of treatment, vitamin C was completely degraded at pH 10, while in the case of pH 7, approximately 82.6% of vitamin C was decomposed. The heightened degradation rate observed under alkaline conditions can be attributed to the accelerated auto-oxidation process of vitamin C [13].

In the subsequent phase, the degradation efficacy of vitamin C in mineral water sourced from Kanjiža Spa (Table 1) was investigated.
Figure 3. The degradation efficiency of vitamin C (0.05 mM) in ultrapure water at different pH values and using SSI, where $c$ is the vitamin C concentration and $c_0$ is the initial concentration of vitamin C (a). Chromatograms obtained after 5 min of photocatalytic treatment of vitamin C (b).

Table 1. The chemical characteristics of the mineral water originating from Kanjiža Spa.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.9</td>
</tr>
<tr>
<td>Sodium (g/L)</td>
<td>1.298</td>
</tr>
<tr>
<td>Potassium (g/L)</td>
<td>0.0097</td>
</tr>
<tr>
<td>Lithium (g/L)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Ammonium (g/L)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Calcium (g/L)</td>
<td>0.0064</td>
</tr>
<tr>
<td>Magnesium (g/L)</td>
<td>0.0027</td>
</tr>
<tr>
<td>Strontium (g/L)</td>
<td>0.0004</td>
</tr>
<tr>
<td>Manganese (g/L)</td>
<td>0.00001</td>
</tr>
<tr>
<td>Iron (g/L)</td>
<td>0.00001</td>
</tr>
<tr>
<td>Aluminum (g/L)</td>
<td>0.00005</td>
</tr>
<tr>
<td>Hydrogen carbonate (g/L)</td>
<td>2.934</td>
</tr>
<tr>
<td>Chloride (g/L)</td>
<td>0.073</td>
</tr>
<tr>
<td>Bromide (g/L)</td>
<td>0.00013</td>
</tr>
<tr>
<td>Iodide (g/L)</td>
<td>0.0006</td>
</tr>
<tr>
<td>Fluoride (g/L)</td>
<td>0.0003</td>
</tr>
<tr>
<td>Nitrate (g/L)</td>
<td>0.0001</td>
</tr>
<tr>
<td>Hydrogen phosphate (g/L)</td>
<td>0.0002</td>
</tr>
<tr>
<td>Sulphate (g/L)</td>
<td>0.0009</td>
</tr>
</tbody>
</table>
Two distinct water samples were employed: mineral water in its natural state (labeled mineral water) and mineral water from which 50% of the initial volume had been evaporated to heighten the mineral concentration (labeled evaporated mineral water). These investigations were conducted under different initial pH values (7 and 10), with results presented in Figure 4.

**Figure 4.** The degradation efficiency of vitamin C (0.05 mM) in ultrapure, mineral and evaporated mineral water at different pH values and using SSI, where \( c \) is the vitamin C concentration and \( c_0 \) is the initial concentration of vitamin C.

Generally, the presence of dissolved organic matter and diverse inorganic ions in natural waters can yield both advantageous and detrimental effects on photodegradation efficiency [19,20]. Our findings revealed that, to a certain extent, the degradation rate of vitamin C was higher in mineral water compared to ultrapure water at both initial pH levels. This increased degradation in untreated mineral water and can be ascribed to the presence of various ions and the naturally higher pH value of mineral water, which hastens degradation. The enhanced efficiency in vitamin C degradation in mineral water may be attributed to the presence of Mg(II) ions, known to bolster photodegradation efficiency [21]. Additionally, sulfate ions react with hydroxyl radicals to form sulfate radicals, which expedite photodegradation [21], or result in the generation of additional hydroxyl radicals within the water environment [22]. Conversely, in evaporated mineral water samples, the degradation of vitamin C under SSI was lower at both initial pH levels compared to other samples (Figure 4). This can potentially be implicated by the heightened concentration of present cations and anions that obstructed the degradation, thereby shielding vitamin C from forced photodegradation under SSI. Specifically, studies by Calza and Pelizzetti [19] explored the impact of halide ions on the removal efficiency of various organic pollutants, with results indicating that chloride and bromide ions hinder degradation, aligning with the findings observed for vitamin C in this study. Furthermore, after 15 min of irradiation, the degradation process ceased, with no further degradation of vitamin C occurring in the final 15 min of irradiation.

Ultimately, to ascertain the most favorable conditions, additional experiments were conducted using mineral water evaporated to 30% and 70% (Figure 5) at initial pH levels of 7 and 10, under SSI.
Our observations revealed that in samples where mineral water was evaporated to 30%, heightened degradation of vitamin C was evident compared to those evaporated to 50% and 70%. This phenomenon can be attributed to the diminished concentration of various ions, which failed to impede the degradation of vitamin C. Conversely, in instances where mineral water samples were evaporated to 70%, lower degradation was noted compared to the 30% evaporation, yet it surpassed that of the 50% evaporation. This behavior is likely attributable to the exceedingly high concentration of ions present in the solution. The decreased degradation efficiency of vitamin C positively confirms the “protective” effect of the concentrated mineral water, which indicates the higher stability-enhancing behavior of the tested water samples compared to the systems with ultrapure water, where higher degradation efficiency was observed.

3.2. In Vitro Assessment of Antioxidative Activity

DPPH, ABTS, and FRAP tests were performed on mineral water samples with and without concentration (evaporation) up to 50%, with the pH adjusted to 5 (Table 2).

Table 2. Antioxidative activities of the thermal mineral water originating from Kanjiža Spa.

<table>
<thead>
<tr>
<th>Sample</th>
<th>IC$_{50}$ (mg/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DPPH</td>
</tr>
<tr>
<td>Mineral water</td>
<td>2.26 ± 0.23</td>
</tr>
<tr>
<td>Mineral water (50%)</td>
<td>5.04 ± 0.12</td>
</tr>
<tr>
<td>Mineral water (pH 5)</td>
<td>2.52 ± 0.09</td>
</tr>
<tr>
<td>Mineral water (50%, pH 5)</td>
<td>19.3 ± 0.45</td>
</tr>
</tbody>
</table>

n.m.—not measurable.

The highest antioxidant activity was measured in mineral water samples without concentration (evaporation) using the DPPH and ABTS methods, proving its possibility to be used as an antioxidant agent. It was not possible to measure the antioxidant activity of the tested samples using the FRAP method. The lowest values of antioxidant activity were observed in the mineral water sample concentrated up to 50% and with a reduced pH value.
3.3. Pharmaceutical Technological Aspects

Since the photolytic experiments confirmed that the degradation of vitamin C is lower in mineral water, indicating the protective behavior, which is also confirmed by the DPPH and ABTS tests, various dermocosmetic products were designed and manufactured on the basis of mineral water from Kanjiža Spa. The production of each dermocosmetic product has shown that modified (concentrated and neutralized) mineral water can serve as an excellent raw material for pharmaceutical and cosmetic product manufacturing, from both organoleptic (Figure 6) and pharmaceutical–technological standpoints.

![Organoleptic examination of the mineral-water-based cream sample.](image)

Each of the prepared products (Figure 7) could serve as a basis for further in vivo assessment in order to confirm the effects of mineral-water-based products on human subjects.

![Primary packaging for the prepared mineral-water-based skincare products (to be used in future cosmetic trials).](image)

Figure 7. Primary packaging for the prepared mineral-water-based skincare products (to be used in future cosmetic trials).

4. Conclusions

Changes in the skin, as the largest and most visible human organ, have a consequential impact on the medical, sociological, and psychological aspects of an individual’s life. Therefore, the possibility of using mineral water represents a basis for the development of skincare cosmetic products with beneficial effects on human health that are also renewable and environmentally safe. In this study, we delved into exploring the potential antioxidant properties inherent in mineral water sourced from Kanjiža Spa. Our investigation centered on monitoring the stability of vitamin C amidst forced photodegradation under simulated solar irradiation, specifically at initial pH levels of 7 and 10 due to its photo-sensibility.
and importance as raw material for skin care products (e.g., sunscreens). The concept that emerged from our research was a notable disparity in the vitamin C photolytic stability when subjected to ultrapure versus mineral water. Notably, we observed heightened degradation rates in alkaline environments, a phenomenon likely attributed to the intensified auto-oxidation of vitamin C beyond a pH of 7. Furthermore, our inquiry extended to scrutinizing the influence of ion concentration on the photodegradation efficiency. To this end, mineral water underwent evaporation processes resulting in concentrations of 30%, 50%, and 70% of its original volume. Interestingly enough, the lowest degradation of vitamin C was detected when mineral water was evaporated to 50%, implicating a potential protective effect. The probable antioxidative effect of mineral water was also confirmed by the results of DPPH and ABTS tests. These findings hold promising implications, particularly for the pharmaceutical and cosmetic industry. Thus, three different dermocosmetic products were developed on the basis of this raw material from Kanjiža Spa.

Given that no results of testing the effects of mineral water from Banja Kanjiža as a raw material for dermocosmetic products have been documented thus far, the results of this work and the products that have resulted from it can be considered very important for future research. Even more so as by harnessing potential antioxidant properties of mineral water, novel formulations, such as environmentally sustainable skincare products, could be designed, offering an ecological alternative to conventional chemical-based solutions commonly found in sunscreen products.

Author Contributions: Conceptualization, S.B. and G.K.; methodology, D.Š.M.; validation, S.B. and N.F.; formal analysis, S.B., N.F. and N.N.; investigation, S.B., N.F. and N.N.; resources, N.J.L.; data curation, S.B. and N.F.; writing—original draft preparation, S.B., N.F., G.K., S.V. and M.K.; writing—review and editing, D.Š.M. and P.P.; visualization, S.B., N.F., G.K., S.V. and M.K.; supervision, D.Š.M.; project administration, S.V. and M.K.; funding acquisition, P.P. and N.J.L. All authors have read and agreed to the published version of the manuscript.

Funding: This work was supported by the Provincial Secretariat for Higher Education and Scientific Research (Grant Number 142-451-2367/2022-01/01) and the Science Fund of the Republic of Serbia (Grant No 7747845, In situ pollutant removal from waters by sustainable green nanotechnologies—CleanNanoCatalyze).

Data Availability Statement: Data is contained within the article.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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