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Research Article

Influence of Light Exposure during Cold Storage of Minimally Processed Vegetables (*Valeriana* sp.)

Angela Zappia, Alessandra De Bruno, Rosita Torino, Amalia Piscopo, and Marco Poiana

Department of AGRARIA, Mediterranea University of Reggio Calabria, Vito, Reggio Calabria 89124, Italy

Correspondence should be addressed to Angela Zappia; angela.zappia@unirc.it

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Minimally processed vegetables are sensitive to leaves discoloration and quality deterioration, and these negative aspects can affect their shelf life. During the manufacturing processing, *Valeriana* leaves were submitted to different dipping acid solutions and then were stored at cold temperature in dark and in light to study the influence of the light exposure on their quality in terms of total free acidity, dry matter percentage, colour, water activity, total bacterial count, antioxidant components, and total antioxidant activity. The results suggest that dark storage is recommended for a better physicochemical quality of *Valeriana* leaves. In particular, light influenced significantly the browning index and hue angle with a significance level of $p < 0.01$ and $p < 0.05$, respectively, whereas both exposure conditions affected total bacterial count and pH ($p < 0.01$). Dipping treatments had an effect on pH, a_w, and total bacterial count, while the storage time influenced with highly significant differences the most of the studied parameters, except for the antioxidant compounds.

1. Introduction

The quality of minimally processed or ready-to-eat vegetables depends mainly on external and internal parameters. Quality changes are due to the product quality at the harvesting and storage conditions during the postharvest period. External parameters, such as the colour, are very important in the leafy vegetables because of the appearance and the capacity to promote the purchasing by the consumer [1].

Usually, leafy vegetables are sold within about 7 days after postharvest treatment, and packaging is aimed to maintain external colour, reducing browning of tissue and improving shelf life. In particular, when the typical green colour of leafy tissues was lost, browning and degradation of carotenoids, chlorophyll, and total phenols take place. Moreover, the yellowing of tissue is a natural discoloration due to the senescence of the leaves successive to the light exposure of the product. For these reasons, the quantification of total pigments and phenols is also very important to determinate the antioxidant activity of vegetables. Moreover, phenolic compounds show variable evolution during the storage, without significantly reducing their content up to an advanced storage [1]. Recently, the effect of light exposure on quality and physiology of fresh fruits and vegetables was studied [2–7]. One of the most important parameters during the storage is temperature: 4°C is considered useful to preserve the quality of leafy vegetables, as reported in the literature [8, 9]. Furthermore, specific pretreatments with acids, such as citric and ascorbic acids, during the leafy dipping process, can improve shelf life and minimise the colour changes. Zhu et al. [10] found that the combination of ascorbic and citric acids was indeed effective in slowing down the rate of enzymatic browning. In particular, citric acid ($C_6H_8O_7$) is of interest for this purpose, since it is inexpensive; so it is widely used as an acidulant agent in food industry [11]. It also proved to promote the retention or even the enhancement of various physical properties of foods, such as colour and texture [10].

The objective of this study is to investigate the influence of light exposure and darkness on physical and chemical qualitative characteristics during the cold storage by monitoring the colour changes (tissue browning/yellowing), the antioxidant activity, and the hygienic state of the product during the storage.

2. Materials and Methods

2.1. Materials. Fresh leaves of *Valeriana* (*Valeriana locusta* L.) were purchased from a local market, stored at 4°C, and successively subjected to different treatments by dipping solutions in a factory (COF SpA, Vibo Valentia) prior to spin-dry and package. The samples were named as follows: T1, control sample dipped in tap water for 5 min; T2, sample dipped in 1% (w/v) citric acid; and T3, sample dipped in 0.5% (w/v) citric acid and 0.5% (w/v) ascorbic acid. The samples were packaged (125 g of weight) in conventional polypropylene antifog bags (25 cm × 20 cm of size, 35 μm of thickness, OTR: 1600 $cm^3 \cdot m^{-2}$ 24 $h^{-1} \cdot atm^{-1}$ according to ASTM D3985, and WVTR: 6 $g \cdot m^{-2}$ 24 h^{-1} according to ASTM F1249) and immediately transported to the laboratory at Mediterranea University of Reggio Calabria where they were stored at 4°C in darkness and light in fluorescence tubes that simulated the commercial exposure of minimally processed vegetables. The fluorescent lights were obtained from three lights (8 W and 430 lm for each light) installed in the storage thermoincubators (950 lux measured by means of an ITT Metrix instrument, Annecy, France). The distance between the sample and light was about 75 cm with a similar illuminance for all samples during storage.

The physicochemical and microbiological analyses were performed at zero, three, seven, ten, fourteen, and sixteen days over the recommended seven days by the producer. Two replicates were done for each of the three treatments. The quality of vegetables dipped in acid solutions was compared with that of vegetables dipped in water.

2.2. Headspace Analysis. Prior to opening the bags, headspace gas composition, expressed as oxygen and carbon dioxide percentages, was determined using the CheckPoint handheld gas analyser (PBI Dansensor Italia Srl, Milan, Italy). The gas sample was taken with a needle inserted through a septum placed on the packages.

2.3. Preparation of Extracts. After opening the bags, the leaves were homogenised in a common blender, and 5 g of the sample was added to 50 ml of distilled water. The contents were mixed in a stomacher and centrifuged at 5,000xg for 5 min. Supernatant solution was collected, and residues were reextracted. The two supernatant solutions were filtered through a paper and combined for the chemical analyses.

2.4. Physicochemical Analysis. For the extracts, titratable acidity, expressed as % of citric acid g^{-1}, and pH (with a pH meter Crison GLP, Barcelona, Spain) were measured according to the AOAC method [12]. Dry matter (% d.m.) was evaluated by loss in weight in an oven at 70°C to constant weight, and water activity (a_w) was measured by means of the AquaLab LITE (Decagon, Inc., Washington, USA) instrument.

Determination of colour was referred to the CIELAB colour space and performed for the parameters L^* (lightness), ranging from 0 (black) to 100 (white), a^* ranging from 60 (red) to −60 (green), and b^* ranging from 60 (yellow) to −60 (blue). The colour space parameters were measured on ten points of the leaves surface by using a tristimulus colorimeter (model CM-700d, Konica Minolta, Osaka, Japan). The mean of the measurements and standard deviation were reported.

The hue angle (H°) describes the relative amounts of redness and yellowness where 0°/360° is defined for red/magenta, 90° for yellow, 180° for green, and 270° for blue or purple, or intermediate colours between adjacent pairs of these basic colours [13, 14]. Hue angle was calculated from a^* and b^* values according to the following formula according to Wrolstad and Smith [15]:

$$\text{hue angle}\,(^\circ) = \arctan\left(\frac{b^*}{a^*}\right). \tag{1}$$

The browning index is an important parameter to define browning in the foods. It represents the purity of brown colour and is calculated using L^*, a^*, and b^* according to Mohammadi et al. [16]:

$$\text{browning index}\,(\text{BI}) = \left[\frac{100\,(x - 0.31)}{0.17}\right], \tag{2}$$

where

$$x = \left[\frac{(a^* + 1.75\,L^*)}{5.6645\,L^* + a^* - 3.012\,b^*}\right]. \tag{3}$$

2.5. Microbiological Analysis. Total bacterial count (TBC) was examined on the samples. At each sample time point (0, 3, 7, 10, 14, and 16 days), ten grams of *Valeriana* were diluted with the sterile Ringer's solution in a stomacher bag filter and homogenised in the BagMixer (Interscience, France) for 5 min, and decimal serial dilutions were prepared and plated on Petri plates. TBC was enumerated on PCA (Plant Count Agar) growth land (Oxoid) at 26°C for 48 h and was expressed as $\log_{10}$ CFU g^{-1}.

2.6. Total Phenolic Content and Antioxidant Activities. *Valeriana* leaves were homogenised in a common blender, and 5 g of the sample was added to 25 mL of methanol : water (80 : 20, v : v), mixed, and then centrifuged at 10,000xg for 10 min according to the method of Zhan et al. [17] with some modifications. Supernatant solution was collected, and residues were reextracted. The two supernatant solutions were filtered through syringe filters (0.45 μm Chromafil RC-45/25) and combined for subsequent analyses.

The method of Singleton and Rossi [18] was followed to determine total phenolic content. 100 μL of the extract was analysed spectrophotometrically at 760 nm after reaction with the Folin–Ciocalteu reagent. The results are reported as mg gallic acid g^{-1}.

The Trolox equivalent antioxidant capacity (TEAC) was determined using the $ABTS^+$ radical cation decolourisation assay, according to the method of Re et al. [19]. 25 μL of the sample extract reacted with 2975 μL of ABTS solution for

6 min in the dark. The absorbance was measured at 734 nm. The TEAC of extracts was expressed as μM·TE·g^{-1}.

Also, DPPH radical-scavenging activity was determined according to the method of Brand-Williams et al. [20]. 50 μL of the sample extract reacted with 2950 μL of DPPH solution for 15 min in the dark. The absorbance was measured at 515 nm. The antioxidant capacities of extracts were expressed as percentage of inhibition according to the following formula:

$$\%\text{inhibition} = \left(\frac{A_{t0} - A_{t\text{end}}}{A_{t0}}\right) \times 100, \quad (4)$$

where A_{t0} is the value of absorbance of DPPH solution at initial time, while $A_{t\text{end}}$ is the value of the absorbance measured after fifteen minutes.

2.7. Statistical Analysis. All experiments were performed in duplicate. The effects of the light, treatment methods, and storage time were evaluated by statistical analysis of variance (one-way ANOVA and multivariate analysis) using the SPSS software (version 15). All data were presented as mean values and standard deviations. Tukey's multiple range test was used to evaluate differences among values, and the statistical significance was defined as $p < 0.05$.

3. Results and Discussion

Changes in atmosphere composition (O_2% and CO_2%) in all packaged samples are shown in Figure 1. During the storage, O_2% was influenced significantly by light exposure ($p < 0.05$). Instead, CO_2% was affected by treatment, with $p < 0.01$, and it showed statistical differences among samples by the post hoc test after three, seven, and ten days of storage (statistical data not shown). Up to ten days of storage, the changes in atmosphere composition could be achieved by natural tissues respiration. Then, CO_2 clearly increased for tissues respiration, as confirmed by Alegria et al. [21], as well the bacterial growth. O_2 percentage decreased for up to ten days, and then, its concentration inside the packaging increased with percentages always lower than the initial one. This aspect cannot be necessarily related to tissues respiration, but it may be probably due to the gas permeability of the used packaging material because of a humidity change around the package after ten days of storage, as reported by Kader et al. [22]: temperature, relative humidity, and air movement around the package can influence the permeability of the film. No correlation between TBC of samples and O_2 concentration inside the packages was found. In fact, TBC was correlated after sixteen days with water activity as demonstrated by Pearson's correlation ($r = 0.660$ and $p < 0.05$ in dark condition and $r = 0.928$ and $p < 0.05$ in light condition).

The light exposure of the samples influenced TBC with a significance of $p < 0.01$ by multivariate statistical analysis, and also, highly significant differences were found among treatments and at each monitoring time from three days of storage in light (Table 1). The graph (Figure 2) shows both an acidic increase and a microbial increase during storage days. After sixteen days of storage, the highest total bacterial count was found in dark conditions in the T1 sample with 6.75 ± 0.00 $\log_{10}$ CFU g^{-1} and in light conditions in the T3 sample with 7.22 ± 0.00 $\log_{10}$ CFU g^{-1}. The sample, treated with citric acid (T2), stored in darkness, was so hygienically better than the same sample stored in light for the lowest TBC (5.93 ± 0.02 $\log_{10}$). Multivariate statistical analysis demonstrated that treatments significantly influence TBC ($p < 0.01$) as also confirmed in the literature: citric acid, as the solute in washing solutions, contributes to contain the microbial growth in carrots [23]. Ascorbic acid is instead more suggested to retain nutritive compounds, as carotenoids [24].

Changes in physicochemical parameters during the storage are given in Tables 2 and 3, respectively, in dark and light conditions. An increment in titratable acidity, expressed as percentage of citric acid, was observed during the time, with highly significant differences among the treatments at the final storage day in light condition ($p < 0.01$; Figure 2). As titratable acidity increased, the pH tended to decrease. The highest acidity was found in the untreated sample (T1) with 0.19 ± 0.02% of citric acid and pH of 6.06 ± 0.13 in darkness and 0.24 ± 0.00% of citric acid and pH of 6.07 ± 0.24 in light, respectively (Table 2). Light exposure did not affect the total acidity during the storage, but it showed a major effect on the pH values as confirmed by multivariate statistical analysis ($p < 0.01$).

In samples dipped in acid solutions, dry matter was higher compared with that in T1 after sixteen days of storage (6.78 ± 0.02% in T2 and 6.85 ± 0.17% in T3 in light condition). As reported in the literature by Hiranvarachat et al. [23], this is probably due to the properties of the weak citric acid, which loosen the cell wall structure.

The browning index and hue angle were calculated by using Equations (1)–(3), and the results are shown in Tables 2 and 3. The browning index measured on samples indicated a very slow rate of occurrence of enzymatic browning, as just reported by Kortey et al. [13] in a study on mushroom colour during storage. Moreover, the light exposure significantly influenced the BI ($p < 0.01$) and hue angle ($p < 0.05$) by multivariate analysis of variance. The trend of BI is illustrated in Figure 3 as the ratio between the value at the given storage time and the initial value (BI_t/BI_0). The T2 sample, treated with citric acid, showed a decrease in terms of BI_t/BI_0. BI increased in the sample dipped in water (T1) with significant differences between darkness condition (38.30 ± 9.05) and light condition (41.30 ± 9.16) at the final storage time ($p < 0.05$). The storage in light involved different browning indexes in samples differently treated; in particular, it was observed after three and ten days ($p < 0.05$). Hue angle decreased during storage time in all samples without statistical differences. The decrease was expected in green leafy vegetables as in the lettuce surface studied by Peiser et al. [25]. The hue angle range was within the 130° region which indicates an apparent green colour. In the T1 sample, it tended to decrease during the time near the 90° region: it suggests leaves yellowing at the end of storage, with $108.03° \pm 5.20$ in darkness condition and $109.43° \pm 5.18$ in light condition.

The TEAC and DPPH radical-scavenging activity were tested for treated samples stored in dark and light

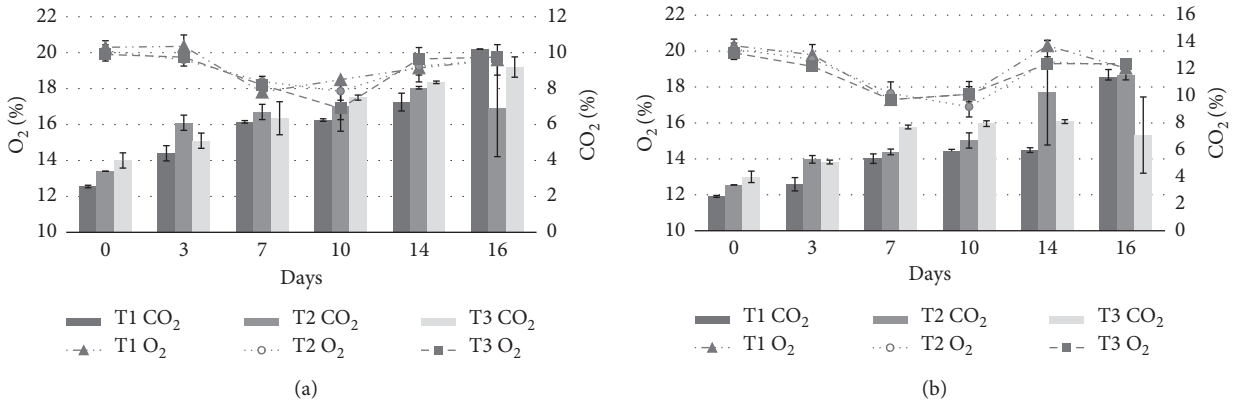

Figure 1: Effect of dark (a) and light (b) conditions on headspace gas composition of *Valeriana* pretreated leaves stored for sixteen days.

Table 1: Results of multivariate analysis for some physicochemical parameters of *Valeriana* leaves with respect to different variables and their interactions.

	Treatments (T)	Storage time (St)	Storage conditions (dark or light) (Sc)	T ∗ St	T ∗ Sc	St ∗ Sc	T ∗ Sc ∗ St
Dry matter	n.s.	**	n.s.	n.s.	n.s.	n.s.	**
pH	**	**	**	**	n.s.	**	**
a_w	**	**	n.s.	**	**	**	**
% O_2	n.s.	**	*	n.s.	n.s.	n.s.	n.s.
% CO_2	**	**	n.s.	**	n.s.	n.s.	**
TBC	**	**	**	**	**	**	**
% citric acid	n.s.	**	n.s.	**	n.s.	n.s.	n.s.
TEAC	n.s.	*	n.s.	*	n.s.	n.s.	n.s.
DPPH assay	n.s.	**	n.s.	n.s.	n.s.	*	n.s.
TPC	n.s.	*	n.s.	*	n.s.	n.s.	n.s.
Hue angle	n.s.	**	*	*	n.s.	n.s.	n.s.
BI	n.s.	**	**	*	n.s.	n.s.	**

**Significance at $p < 0.01$; *significance at $p < 0.05$; n.s.: not significant.

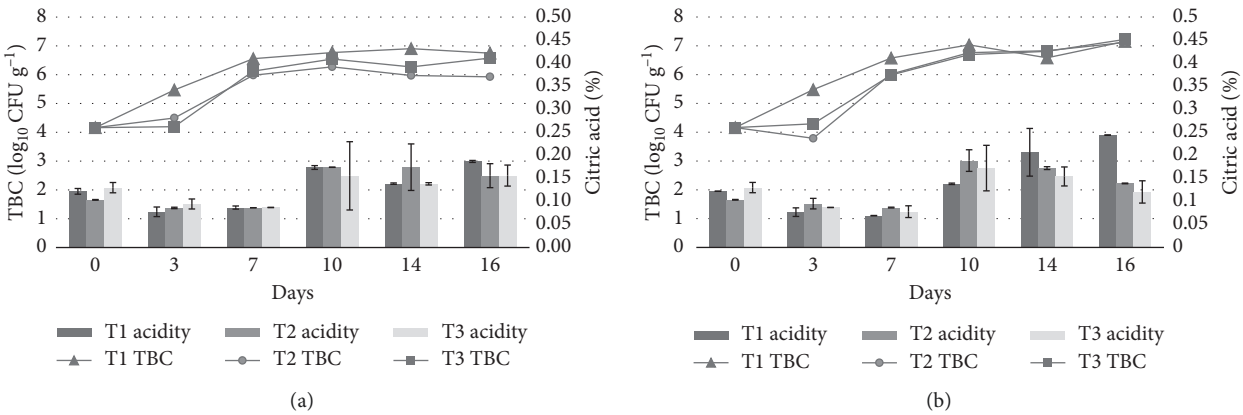

Figure 2: Effect of dark (a) and light (b) conditions on total bacteria count and titratable acidity of *Valeriana* pretreated leaves stored for sixteen days.

conditions. The T3 sample manifested the highest antioxidant activity by TEAC after production probably to the combined effect of mixed acids in dipping ($385.06 \pm 20.26\,\mu$M·TE·g^{-1}). No statistical differences were observed among treated samples at each monitoring storage time with the exception of samples stored after seven days ($p < 0.01$). Table 1 shows that the storage time influenced the TEAC parameter with significance ($p < 0.01$). In particular, it was

Table 2: Physicochemical parameters of pretreated leaves of *Valeriana* stored in dark condition.

Analyses on samples		Storage days in dark condition					
		0	3	7	10	16	Sig.
Dry matter (%)	T1	6.63 ± 0.41	6.63 ± 0.13	6.23 ± 0.04	6.49 ± 0.20	6.69 ± 0.58	n.s.
	T2	6.53 ± 0.02^{ab}	6.56 ± 0.07^{ab}	6.76 ± 0.26^{ab}	6.82 ± 0.04^{a}	7.06 ± 0.24^{a}	*
	T3	6.92 ± 0.00^{a}	6.77 ± 0.04^{ab}	6.29 ± 0.00^{c}	6.48 ± 0.06^{bc}	6.69 ± 0.15^{ab}	**
pH	T1	6.60 ± 0.06	6.34 ± 0.02	6.18 ± 0.18	6.34 ± 0.33	6.06 ± 0.13	n.s.
	T2	6.8 ± 0.02^{a}	6.42 ± 0.01^{c}	6.50 ± 0.03^{bc}	6.45 ± 0.01^{bc}	6.54 ± 0.04^{b}	**
	T3	6.70 ± 0.04^{ab}	6.32 ± 0.01^{d}	6.80 ± 0.06^{a}	6.53 ± 0.03^{c}	6.66 ± 0.05^{abc}	**
a_w	T1	0.979 ± 0.001^{c}	0.984 ± 0.002^{ab}	0.981 ± 0.001^{bc}	0.986 ± 0.000^{a}	0.980 ± 0.000^{bc}	**
	T2	0.980 ± 0.000^{bc}	0.981 ± 0.001^{bc}	0.982 ± 0.001^{b}	0.986 ± 0.000^{a}	0.979 ± 0.000^{c}	**
	T3	0.980 ± 0.001^{ab}	0.982 ± 0.001^{ab}	0.982 ± 0.000^{a}	0.981 ± 0.000^{ab}	0.979 ± 0.000^{bc}	**
Browning index	T1	37.00 ± 5.77	36.98 ± 5.81	38.63 ± 5.14	39.19 ± 6.13	38.28 ± 9.05	n.s.
	T2	40.22 ± 6.59	38.32 ± 8.11	38.13 ± 6.22	34.30 ± 6.87	32.15 ± 6.88	n.s.
	T3	36.76 ± 6.01	37.09 ± 6.83	41.81 ± 8.94	32.89 ± 11.34	36.83 ± 9.38	n.s.
Hue angle	T1	112.03 ± 3.16	111.65 ± 2.83	112.39 ± 2.55	113.51 ± 2.80	108.03 ± 5.20	n.s.
	T2	110.85 ± 2.56	111.47 ± 1.49	112.85 ± 2.78	112.74 ± 2.08	112.92 ± 2.95	n.s.
	T3	112.45 ± 2.84	110.93 ± 2.85	111.43 ± 3.24	115.97 ± 7.20	112.04 ± 1.95	n.s.
TEAC (μM·TE·g^{-1})	T1	268.51 ± 33.30	320.86 ± 27.67	284.03 ± 76.91	271.63 ± 44.64	320.60 ± 4.03	n.s.
	T2	285.12 ± 20.43	391.33 ± 11.39	308.04 ± 41.46	317.03 ± 39.73	364.82 ± 77.13	*
	T3	385.06 ± 20.26	386.38 ± 44.36	351.13 ± 61.00	292.98 ± 44.28	311.81 ± 30.62	n.s.
DPPH assay (% of inhibition)	T1	20.19 ± 1.78	22.43 ± 6.52	21.00 ± 0.391	7.83 ± 0.83	19.94 ± 1.59	n.s.
	T2	20.16 ± 0.15^{ab}	25.10 ± 0.19^{a}	20.23 ± 4.22^{ab}	14.59 ± 1.73^{b}	20.38 ± 3.27^{ab}	*
	T3	23.10 ± 0.54^{ab}	24.79 ± 3.61^{a}	20.81 ± 0.39^{ab}	15.83 ± 3.35^{ab}	16.90 ± 3.97^{ab}	*
Total phenolic content (mg gallic acid g^{-1})	T1	1016 ± 4.54	1168 ± 240.02	1111 ± 173.36	1271 ± 117.04	1404 ± 38.32	n.s.
	T2	1108 ± 72.66	1147 ± 2.68	1313 ± 255.70	1222 ± 238.02	1347 ± 26.41	n.s.
	T3	1264 ± 25.44	1345 ± 232.15	1070 ± 141.16	1060 ± 158.10	1294 ± 142.36	n.s.

Results are presented as the mean value ± standard deviation. $n = 2$; means within a row with different letters are significantly different by Tukey's post hoc test; **significance at $p < 0.01$; *significance at $p < 0.05$; n.s.: not significant.

demonstrated by one-way ANOVA during the storage in dark condition: only TEAC of the T2 sample stored in dark condition increased during storage time with significant differences ($p < 0.05$) (Table 2). The light exposure of the samples did not affect antioxidant activities as shown by multivariate analysis (Table 1).

Storage time highly influenced DPPH radical-scavenging activity by multivariate analysis with $p < 0.01$ (Table 1). More precisely, the dark condition influenced this parameter during the time more than the light as demonstrated by one-way ANOVA (Table 2): during the storage, DPPH radical-scavenging activity increased in T2 with the highest value of $20.38 \pm 3.27\%$ at the end, while a decrease was observed in T3 after sixteen days with $p < 0.05$ in dark condition. Probably, presence of citric acid had influenced this qualitative parameter: so the treatment with citric acid (T2) is more suggested to improve *Valeriana* leaves' antioxidant capacity.

The light exposure of samples did not affect total phenolic content (about 1110 mg gallic acid kg^{-1}), and it did not change with significance in samples during the storage except for the untreated sample (T1) stored in light condition ($p < 0.05$). In particular, the total phenolic content tended to increase during the storage days, particularly in light conditions with a final content of 1464.82 ± 151.77, 1404.95 ± 205.04, and 1378.91 ± 136.24 mg gallic acid kg^{-1} in T1, T2, and T3 samples, respectively. This amount of total phenolic compounds may also play an inhibitory effect on the browning appearance, as just reported by Ferrante et al. [26]. Positive correlations between phenolic compounds and antioxidant activities (by TEAC and DPPH assay) were found only at time zero ($r = 0.792$ and $p < 0.05$ and $r = 0.844$ and $p < 0.05$, respectively, for the two assays), showing that the increase in TEAC of the T2 sample stored in darkness was not probably related to the phenolic content. Therefore, these last compounds cannot be used to estimate the overall health status and probably also the antioxidant property of leafy vegetables during storage, as suggested by Ferrante and Maggiore [27], and that the antioxidant activities in the *Valeriana* species may be attributed to some other compounds than the phenolics, flavonoids, and tannins as reported by Jugran et al. [28].

4. Conclusion

In conclusion, the results of this study showed that the quality of *Valeriana* minimally processed vegetables can be improved by treatments at the processing. The samples were stored for sixteen days over the recommended seven days by the producer with a total bacteria count within the satisfactory limits of 10^6 $\log_{10}$ CFU g^{-1}, although a dipping in 1% of citric acid is recommended to limit even more the bacterial growth. Most of the studied qualitative parameters were significantly affected by the time of storage, with the exception of the antioxidant activity and total phenolic content. The darkness storage should be preferred than light exposure for a better leafy colour. Treatments of *Valeriana* leaves with a mixture of citric and ascorbic acids (T3) compared with citric acid (T2) were not suggested to

Table 3: Physicochemical parameters of pretreated leaves of *Valeriana* stored in light condition.

Analyses on samples		Storage days in light condition					
		0	3	7	10	16	Sig.
Dry matter (%)	T1	6.63 ± 0.41	6.23 ± 0.15	6.28 ± 0.16	6.86 ± 0.13	6.53 ± 0.25	n.s.
	T2	6.53 ± 0.02^{ab}	6.30 ± 0.23^{ab}	6.27 ± 0.13^{ab}	6.52 ± 0.03^{a}	6.78 ± 0.02^{a}	*
	T3	6.92 ± 0.00^{a}	6.18 ± 0.10^{ab}	6.55 ± 0.23^{c}	6.46 ± 0.16^{bc}	6.85 ± 0.17^{ab}	*
pH	T1	6.60 ± 0.06	6.44 ± 0.02	6.92 ± 0.03	6.57 ± 0.02	6.07 ± 0.24	**
	T2	6.89 ± 0.02^{a}	6.25 ± 0.12^{c}	6.78 ± 0.12^{bc}	6.52 ± 0.06^{bc}	6.65 ± 0.06^{b}	**
	T3	6.70 ± 0.04^{ab}	6.35 ± 0.00^{d}	6.93 ± 0.04^{a}	6.52 ± 0.05^{c}	6.67 ± 0.01^{abc}	**
a_w	T1	0.979 ± 0.001^{c}	0.981 ± 0.001^{ab}	0.983 ± 0.001^{bc}	0.981 ± 0.000^{a}	0.980 ± 0.000^{bc}	**
	T2	0.980 ± 0.000^{bc}	0.985 ± 0.001^{bc}	$0.982 \pm \pm 0.001^{b}$	0.982 ± 0.000^{a}	0.980 ± 0.000^{c}	**
	T3	0.980 ± 0.001^{ab}	0.981 ± 0.001^{ab}	$0.982 \pm \pm 0.000^{a}$	0.981 ± 0.000^{ab}	0.982 ± 0.000^{bc}	**
Browning index	T1	37.00 ± 5.77	44.76 ± 6.52	41.45 ± 8.17	35.27 ± 12.06	41.26 ± 9.16	n.s.
	T2	40.22 ± 6.59	39.58 ± 8.71	42.44 ± 7.44	45.59 ± 10.55	33.99 ± 6.57	n.s.
	T3	36.76 ± 6.01	35.42 ± 8.76	38.91 ± 7.76	43.04 ± 11.43	38.49 ± 8.13	n.s.
Hue angle	T1	112.03 ± 3.16	110.54 ± 2.64	110.59 ± 3.13	115.07 ± 6.48	109.43 ± 5.18	n.s.
	T2	110.85 ± 2.56	110.91 ± 2.21	111.87 ± 2.19	110.16 ± 11.90	109.97 ± 5.30	n.s.
	T3	112.45 ± 2.84	111.95 ± 3.72	112.46 ± 2.61	111.63 ± 3.45	111.61 ± 2.56	n.s.
TEAC (μM·TE·g^{-1})	T1	268.51 ± 33.30	295.46 ± 87.30	352.7 ± 19.12	291.93 ± 92.99	411.286 ± 36.16	n.s.
	T2	285.12 ± 20.43	334.64 ± 32.00	245.4 ± 9.03	294.3 ± 48.35	303.332 ± 19.57	n.s.
	T3	385.06 ± 20.26	311.27 ± 42.07	306.6 ± 7.45	322.19 ± 9.06	302.914 ± 94.24	n.s.
DPPH assay (% of inhibition)	T1	$20.191 \pm \pm 1.78$	21.568 ± 1.25	17.51 ± 3.66	19.092 ± 0.14	19.9573 ± 0.31	n.s.
	T2	20.163 ± 0.15^{ab}	25.933 ± 4.90^{a}	18.9 ± 2.40^{ab}	20.261 ± 0.19^{b}	18.307 ± 3.25^{ab}	n.s.
	T3	23.097 ± 0.54^{ab}	20.812 ± 0.01^{a}	20.2 ± 0.04^{ab}	20.625 ± 3.22^{ab}	21.8223 ± 1.00^{ab}	n.s.
Total phenolic content (mg gallic acid kg^{-1})	T1	1017 ± 4.54	1378 ± 96.15	979 ± 53.51	1084 ± 142.52	1465 ± 151.77	*
	T2	1109 ± 72.66	1245 ± 212.10	1657 ± 209.43	1315 ± 14.71	1405 ± 205.04	n.s.
	T3	1265 ± 25.44	1286 ± 4.60	1058 ± 379.01	1136 ± 144.30	1379 ± 136.00	n.s.

Results are presented as the mean value ± standard deviation. $n = 2$; means within a row with different letters are significantly different by Tukey's post hoc test; **significance at $p < 0.01$; *significance at $p < 0.05$; n.s.: not significant.

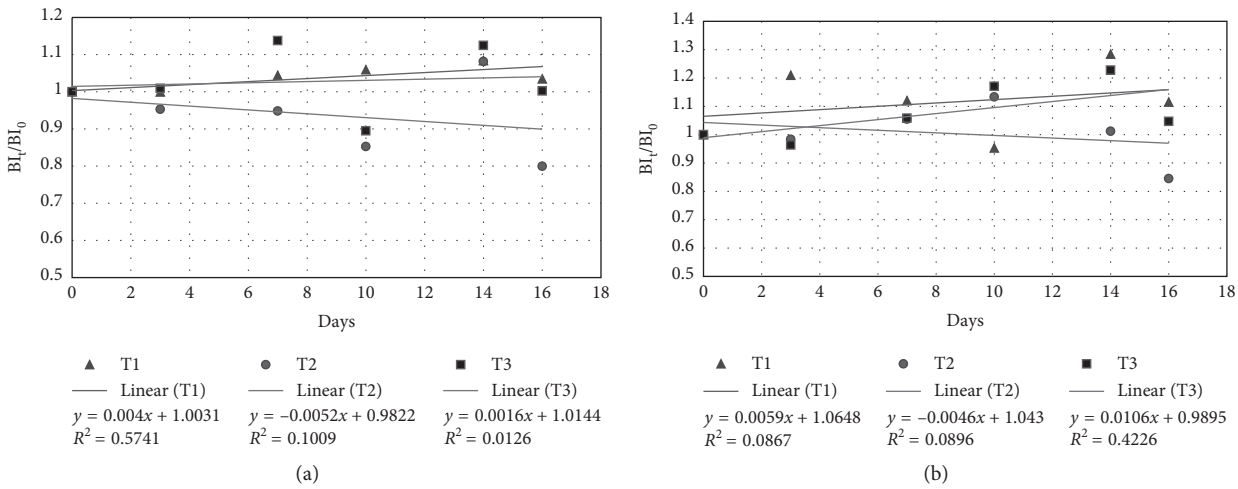

Figure 3: Leaves discoloration expressed as the browning index (BI) in dark (a) and light (b) conditions. Data are the ratio between the value at a given storage time (t) and the initial value (0).

preserve green leaves of *Valeriana* for the results on BI values. Moreover, the T3 samples did not show high antioxidant activity in terms of TEAC and DPPH radical-scavenging activity and possessed a lower total phenolic content compared with the other samples. Finally, darkness storage is suggested to improve the qualitative and colour parameters and to preserve up to sixteen days the green leafy vegetables as *Valeriana*, supported by a dipping in 1% of citric acid.

Data Availability

All data generated or analysed during this study are included in this article and are also available from the corresponding author on reasonable request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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