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Effect of Oxalic Acid Treatments and Modified Atmosphere Packaging on the Quality Attributes of Rocket Leaves during Different Storage Temperatures

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Abstract: The effects of combinations of oxalic acid (OA) treatment with modified atmosphere packaging on the quality and biochemical content changes of rocket (*Eruca sativa* Mill. cv. Bengi) leaves were examined. After harvest, selected leaves were dipped into an aqueous solution containing different concentrations of oxalic acid (0-control, 0.25 mM, 0.5 mM, and 1 mM) for 1 min. Treated samples were dried and placed in modified atmosphere packages. Treated rockets were stored at two different temperatures (0 °C and 10 °C) and 90 ± 5% relative humidity conditions for 10 days. Leaves were analyzed at 2-day intervals for some quality and biochemical parameters during storage. OA-treated leaves were greener than those of the control group. At the end of the storage, high doses (1 mM) of OA applications successfully suppressed the respiration rate (0 °C: 63.12 mL CO₂ kg⁻¹ h⁻¹, 10 °C: 78.09 mL CO₂ kg⁻¹ h⁻¹) and retarded the weight loss (0 °C: 0.14%, 10 °C: 0.49%) and color discoloration (0 °C: ΔE 7.23, 10 °C: ΔE 8.34) of rocket leaves. In addition, OA treatments decreased the vitamin C losses and chlorophyll degradation. In conclusion, rocket leaves could be stored at 0 °C for 8–9 days with 1 mM OA treatment and 6 days with the control treatment and at 10 °C for 6–7 days with 1 mM OA treatment and 4 days with the control (C) treatment with a minimum quality loss under MAP conditions.

Keywords: *Eruca sativa*; oxalic acid; quality; storage; yellowing



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1. Introduction

Vegetables undergo numerous biological and physiological changes following harvest. As a result of the acceleration of biochemical reactions, including respiration rate and ethylene production in vegetables after harvest, the concentrations of some substances (including color substances, vitamins, organic acids, and oils/fats) that determine the quality and nutritional content of the products change, water loss increases, and color changes take place [1]. Therefore, vegetables cannot be stored for very long following harvest [2,3]. The best way to preserve postharvest quality by delaying the senescence or deterioration of products is to minimize respiration, and the most effective way to do this is to reduce the ambient temperature. In addition to cold storage, heat treatments, edible coatings, ozone applications, modified atmosphere packaging, controlled atmosphere storage, and chemical applications have been widely adopted to increase vegetables' storage and shelf life and maintain their quality for extended periods [4]. However, the fact that the toxic effects of chemical applications do not entirely disappear in products with short storage periods, including vegetables, resulted in a preference for natural applications in the post-harvest period [5].

Oxalic acid (OA) is a natural organic acid with the formula H₂C₂O₄. It is abundantly found in many plants (sorrel, rocket, peas, tomatoes, spinach, etc.) [6]. As the final metabolic product in plants, OA is involved in many vital functions, such as the response to environmental stressors and resistance [7]. In recent studies, exogenously applied OA at non-toxic

concentrations has been reported to reduce enzymatic browning in litchi [8], control diseases and rot in peaches and kiwifruit, reduce respiration rate and ethylene production and maintain nutritional quality [9,10], extend shelf life in bananas and plums [11,12], maintain fruit quality in cherries [13], stimulate the antioxidant system and phenolic content of lemons [14], and regulate ethanol fermentation in kiwifruit [15]. However, such studies conducted with vegetables have been very limited. Exogenously applied OA has been reported to delay quality losses and extend shelf life in tomatoes [16], artichokes [17], asparagus [18], lettuce, and rocket [19].

Vegetables play an essential role in human nutrition thanks to their vitamin and mineral content. Nutritionists state that consuming fruit and vegetables reduces the risk of many diseases and contributes significantly to human health [20]. Therefore, in line with the increase in people's interest in health and quality of life in recent years, there has been an increase in the demand for healthy and fresh products [21]. Particularly, sorted and washed fresh vegetables have been increasingly attracting consumers' attention, especially working people, due to their ease of use. In Turkey, the production of parsley, mint, dill, cress, and rocket, among the vegetables of which the leaves are eaten, has increased significantly in recent years. Between 2012 and 2022, the increase in production volume was 86.5% for parsley, 113.6% for mint, 128.4% for cress, 252.6% for dill, and 429.0 % for rocket. Rocket production in Turkey was 7689 tons in 2012 and increased to 40,674 tons in 2022 [22]. Rocket (*Eruca sativa* Mill.) belongs to the *Brassicaceae* family [23] and can grow naturally in the Mediterranean Basin. Rocket is gaining popularity worldwide due to its health benefits. Glucosinolates give rocket, like other members of this family, a unique and rich aroma [24]. However, due to the high metabolic activity in vegetables of which the leaves are consumed, such as rocket, yellowing and water loss occur faster, shortening their shelf life [25,26]. Yellowing due to chlorophyll breakdown, especially during storage, reduces the marketability of rocket [27,28]. Considering the nutritional value and health value of rocket, its aroma, and the increase in production, there is a need to investigate the correct storage conditions and post-harvest practices to minimize the losses that may occur after harvest.

In line with this information, this study aimed to investigate the effects of post-harvest OA application on quality changes and biochemical contents of rocket leaves at different storage temperatures.

2. Materials and Methods

2.1. Reagents

Oxalic acid ($\geq 97\%$), Tween[®] 20, methanol (99.9%), Trolox standard, and acetone were obtained from Sigma Chemical Co. (St. Louis, MO, USA). Folin-Ciocalteu's and gallic acid standard were purchased from Merck Co. (Rahway, NJ, USA). The chemicals used in the preparation of the FRAP solution (2, 4, 6-Tri(2-pyridyl)-s-triazine, iron (3) chloride hexahydrate, and sodium acetate) were also obtained from Merck Co.

2.2. Plant Material

Rockets were grown with a photoperiod of 16 h, an ambient temperature of 21–22 °C, and a relative humidity of 60–70% under green greenhouse conditions. Commercially grown rockets (*Eruca sativa* Mill. cv. Bengi) were harvested (~18–20 cm length) in Antalya-Turkey in the early morning and immediately transported to the Laboratory of the Postharvest Physiology. In the laboratory, the roots were cut with sharp scissors, and foreign materials and discolored or bruising leaves were discarded by hand at 5 °C. The fully green leaves without roots were used as plant material. Leaves were dipped in tap water (at ~5–6 °C) to remove soil particles for 1 min.

2.3. Oxalic Acid Treatments and Storage Conditions

Selected leaves were randomly divided into 8 groups for the following treatments (T) (3500 \pm 150 g leaves for each group):

T1-T2-T3-T4: Leaves were dipped in aqueous solutions (pH 6.5 and at 5 °C) of OA at different doses for 1 min: 0 (control), 0.25 mM, 0.5 mM, and 1 mM, stored at 0 ± 1 °C.

T5-T6-T7-T8: Leaves were dipped in aqueous solutions (pH 6.5 and at 5 °C) of OA at different doses for 1 min: 0 (control), 0.25 mM, 0.5 mM, and 1 mM, stored at 10 ± 1 °C.

Control groups were dipped in distilled water (5 °C) for 1 min. Dipping time (1 min) was determined according to a previous study about rocket plants [19]. Storage temperatures were chosen to simulate shelf (market) conditions (10 ± 1 °C) and normal cold storage temperatures (0 ± 1 °C) for rocket leaves. Tween 20 (0.1%) was also added to enhance infiltration of all aqueous solutions as a surfactant. After dipping treatments, the leaves were spun in a salad spinner to dry for about 2 min and placed in modified atmosphere packages (LDPE) (about 200 ± 50 g per package) at 5 °C. For all treatments, 120 packages (3 replicates × 8 treatments × 5 storage periods – day 0 excluded) were stored for 10 days with 90 ± 5% relative humidity (RH). About 400–450 g of leaves were selected for initial (day 0) analysis. Initially and at 2-day intervals during storage, leaves were analyzed to determine weight loss, respiration rate, leaf color, antioxidant activity, total chlorophyll content, total phenol content, ascorbic acid (vitamin C) content, yellowing, and external appearance.

2.4. Physical and Chemical Analysis

2.4.1. Weight Loss and Respiration Rate

The individual modified atmosphere packages (each package was considered as a replicate, 3 replicates) were weighed at the beginning of the storage (day 0) and placed in the cold storage rooms. The analysis days (2, 4, 6, 8, and 10 days) MAPs were weighed again and calculated according to the following Equation (1):

$$\text{Weight loss (\%)} = [(\text{First weight} - \text{Last weight}) / \text{First weight}] \times 100 \quad (1)$$

The respiration rate of the leaves was determined by placing (weight 75–80 g leaves) in a 1 L glass jar hermetically sealed for 30 min [17]. Afterwards, the gas sample was taken and injected into a gas chromatograph (Agilent 6890N, Palo Alto, CA, USA) equipped with a thermal conductivity detector. Measurements were performed with 3 replicates, and results were expressed as mL CO₂ kg⁻¹ h⁻¹.

2.4.2. Leaf Color, Yellowing, and External Appearance

Leaf color (L*, a* and b*) was determined at two points on the leaf surface with a colorimeter (Minolta CR-200, Ramsey, NJ, USA). The colorimeter was calibrated with a white plate. Color changes (ΔE) at each sampling day were calculated from L*, a*, and b* values similar to Cefola and Pace [19]. Measurements were performed with 3 replicates, and each replicate contained 20 leaves. ΔE was calculated according to the following Equation (2):

$$\Delta E = [(L^*_0 - L^*)^2 + (a^*_0 - a^*)^2 + (b^*_0 - b^*)^2]^{1/2} \quad (2)$$

Yellowing was determined based on a five-point hedonic scale (1: dark green, 2: light green, 3: yellowish-green, 4: greenish-yellow, 5: yellow). When the leaves' scores reached 3, they were noted as unmarketable and at the end of their shelf life [25]. The degree of external appearance has a nine-point hedonic scale (≤1–4: poor, 9: excellent). Evaluations were made with 3 replicates. The yellowing and external appearance evaluation panel consisted of 7 members of the research staff (Horticulture Department) who were experienced in sensory analysis of horticultural crops.

2.4.3. Total Phenolic Content and Antioxidant Activity

Extraction for total phenolic content and antioxidant activity: The leaf samples (5 g) were placed in a tube (50 mL) and 80% methanol (5 mL) was added. The samples with methanol were crushed by using a homogenizer. The homogenized samples were placed in dark conditions (14–16 h at 4 °C), and supernatants were stored at –20 °C until the

day of analysis (up to a week) [29]. Total phenolic content was determined using the Folin-Ciocalteu method as described and modified by Lola-Luz et al. [30]. The standard curve was developed using gallic acid standard. The absorbance was read at 725 nm using a spectrophotometer (Varian Cary Bio 100, Mulgrave, Victoria, Australia). Measurements were performed with 3 replicates. Results were calculated as mg of gallic acid equivalent (GAE) per g fresh weight (FW).

The ferric reducing antioxidant power (FRAP) assay was used to evaluate the antioxidant capacity of rocket leaves. All the equipment and chemicals and the FRAP method were chosen and determined according to the method stated by Gutiérrez et al. [31]. The absorbance was read at 593 nm using a spectrophotometer. Measurements were performed with 3 replicates. The calibrating curve was developed using the Trolox standard. Results were calculated as Trolox equivalents (Trolox Eq) in g kg^{-1} FW.

2.4.4. Vitamin C and Total Chlorophyll Content

Vitamin C analysis of the leaves was determined by high-performance liquid chromatography (HPLC) (Agilent Technologies Inc.). The leaf sample (10 g) with the extraction medium (20 mL) was homogenized. The HPLC conditions and method were chosen according to the procedure reported by Martínez-Sánchez et al. [32]. Measurements were performed with 3 replicates. The results were expressed in mg per kg of FW.

For total chlorophyll content analysis, chopped leaves (5 g) were extracted in 80% acetone (Sigma-Aldrich, Steinheim, Germany) with a homogenizer. The extracted samples were centrifuged, and the supernatants were collected. Measurements were performed with 3 replicates. The absorbency of acetone extracts was measured at 663 and 645 nm with the spectrophotometer [33].

2.5. Statistical Analysis

The study was set up according to a completely factorial randomized design. The measurements were made in triplicate. All data obtained from this study were statistically evaluated by the SPSS 19.0 package program. Main effects (treatments and storage periods) and interactions (treatments \times storage periods) were analyzed, and means were compared by Tukey's test at a significance level of 0.05. The correlation matrix and principal components analysis (PCA) were obtained from the R-core program.

3. Results and Discussion

3.1. Weight Loss and Respiration Rate

The weight loss (%) of rocket leaves increased steadily at both storage temperatures (Figure 1A). However, in general, it can be argued that these increases were minimal due to the high moisture content in MAP and relatively low water loss. Similarly, Manolopoulou and Mallidis [34] reported that high CO_2 , low O_2 , and high humidity in MAP with prolonged storage time effectively reduced water loss from the products and thus weight loss. In the study, on day 2 of storage, weight loss ranged between 0.08% and 0.11% at 0 °C and between 0.03% and 0.08% at 10 °C. At the end of storage on day 10, weight loss values were between 0.14% and 0.46% at 0 °C and between 0.47% and 1.02% at 10 °C. It was determined that the weight loss of rocket leaves stored at 10 °C was higher than those stored at 0 °C (Figure 1A). This can be explained by the fact that respiration is better suppressed at low temperatures, and the metabolic rate is slowed down. Erbaş and Koyuncu [12] reported that the weight loss in the products increased due to the removal of water from the tissues during respiration; thus, the respiration rate was effective in weight loss. This is supported by the fact that OA treatments (especially 1 mM OA) were more effective than the control treatment at both storage temperatures in terms of reducing weight loss and suppressing respiration rate.

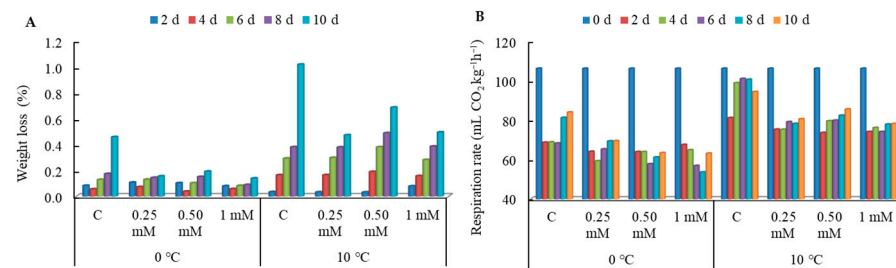


Figure 1. The effects of different OA treatments and storage temperatures on the weight loss (A) and respiration rate (B) of rocket leaves in MAP during storage. C: Control, d: days.

Respiration rate is one of the most critical factors affecting the quality and shelf life of products after harvest. Therefore, it is essential to suppress or slow down the respiration rate of products. As shown in Figure 1B, the respiration rate of the rocket leaves was measured as $106.04 \text{ CO}_2 \text{ kg h}^{-1}$ at the beginning, and on the second day of storage, the respiration rate decreased compared to the beginning and was between $63.92 \text{ mL CO}_2 \text{ kg h}^{-1}$ (0.5 mM , $0 \text{ }^\circ\text{C}$) and $81.11 \text{ mL CO}_2 \text{ kg h}^{-1}$ (C, $10 \text{ }^\circ\text{C}$). The decrease compared to the initial values can be explained by the action of lowering the ambient temperature and placing the products under MAP conditions. As expected, since the metabolic activity of rocket leaves stored at low temperatures slowed down, respiration rates were also lower. At the end of storage on day 10, the lowest respiration values ($63.12 \text{ mL CO}_2 \text{ kg h}^{-1}$, $0 \text{ }^\circ\text{C}$ and $78.09 \text{ mL CO}_2 \text{ kg h}^{-1}$, $10 \text{ }^\circ\text{C}$) were obtained from 1 mM OA treatment at both storage temperatures. All OA treatments were effective in suppressing the respiration rate compared to the control treatment (Table 1). In particular, the 1 mM OA dose was the best suppressing treatment for respiration rate at both storage temperatures (Figure 1B). This may be explained by the fact that OA application slows down the metabolic activity of the products. Our results are in accordance with previous works on vegetables [17,19] and fruit [12,35] treated with OA, which has been linked to a lower metabolic activity induced by OA.

Table 1. *p* values for storage period; treatments and their interactions for rocket leaves.

Parameters	0 °C			10 °C		
	SP	T	SP × T	SP	T	SP × T
WL	**	*	ns	**	**	**
RR	**	**	ns	**	**	**
ΔE	**	**	**	**	**	ns
Yellowing	**	**	*	**	**	**
EE	**	**	**	**	**	**
TPC	*	**	ns	**	*	ns
AOA	*	*	ns	*	*	ns
Vitamin C	*	**	ns	**	**	ns
TC	**	*	**	**	**	**

SP: Storage period, T: Treatments, WL: Weight loss, RR: Respiration rate, ΔE: Leaf color, EE: External appearance, TPC: Total phenolic content, AOA: Antioxidant activity, TC: Total chlorophyll content. Ns represents non significance at $p < 0.05$, * represents significance at the 0.05 level, ** represents significance at the 0.01 level.

3.2. Leaf Color, Yellowing, and External Appearance

Yellowing is the biggest ripening symptom in green leafy vegetables [26]. The rocket leaves' color and appearance were affected by treatments and storage temperature (Table 1). In line with the prolonged storage period, yellowing increased in the leaves, resulting in color and external appearance deterioration. The color change in the rocket leaves started on the second day, and the highest color change (ΔE : 8.48, $0 \text{ }^\circ\text{C}$ and 11.74, $10 \text{ }^\circ\text{C}$) was detected in the control group at both storage temperatures on day 10 at the end of storage. At the end of storage, the 1 mM OA dose (ΔE : 7.23, $0 \text{ }^\circ\text{C}$ and 8.34, $10 \text{ }^\circ\text{C}$) was the most

effective treatment in color preservation at both storage temperatures (Figure 2A). In line with the color change, yellowing and external appearance scores also increased during storage. On the 10th day of storage, the rocket leaves stored at 10 °C had the highest score in terms of yellowing, while the lowest scores were obtained from those stored at 0 °C. At the end of storage, the control group (4.50 score: 0 °C, 4.83 score: 10 °C) was determined to have the highest yellowing scores at both storage temperatures. The lowest yellowing scores were found in 1 mM OA treatment (3.50 score: 0 °C, 4.33 score: 10 °C) at both temperatures (Figure 2B). At the end of storage, all OA treatments were more effective than the control treatments in terms of yellowing and external appearance (Figure 2B,C). The external appearance scores of the rocket leaves were not significantly changed in the initial 4 days of storage, but after the 4th day, the differences between the treatments became more apparent. At the end of storage, the lowest external appearance scores (4.50: 0 °C, 2.83 score: 10 °C) were obtained from the control groups. As expected, in parallel with the increase in temperature, the external appearance scores of rocket leaves stored at 0 °C were higher than those stored at 10 °C. During storage, the highest external appearance scores were generally found in the 1 mM OA treatment at both storage temperatures (Figure 2C). It was thought that the effect of OA on color change, yellowing, and external appearance could be explained by a slowdown of chlorophyll synthesis and lipid peroxidation, which is known to have an impact on quality. The positive effects of OA on color and appearance have also been reported in studies conducted with different vegetable and fruit species [15,19,36].

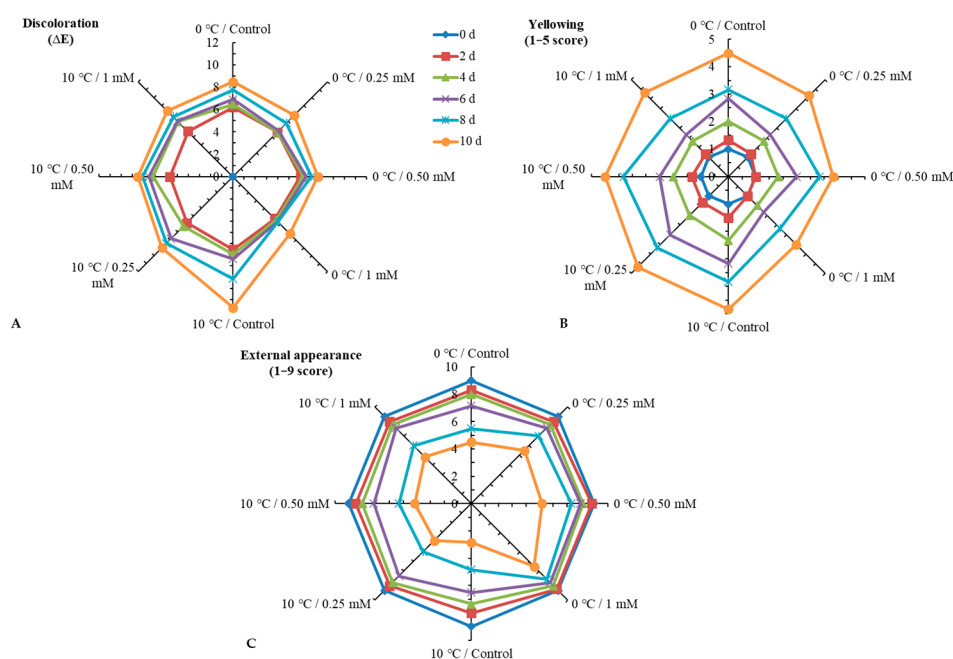


Figure 2. The effects of different OA treatments and storage temperatures on the leaf color (discoloration) (A), yellowing (B), and external appearance (C) of rocket leaves in MAP during storage. d: days.

3.3. Total Phenolic Content and Antioxidant Activity.

Phenolic compounds, one of the essential antioxidant substances in human nutrition [37], are known as secondary metabolism products of plants and are involved in the formation of sensory properties and coloration of products [38]. It has been known that changes in the phenolic content of fruit or vegetables after harvest can be affected by many factors, including species and variety, ripeness, and harvest time. The TPC values of rocket leaves, albeit not regularly, increased in parallel with the prolonged storage period. The increases were rapid from the beginning of storage until day 6 and remained stable on days 8 and 10. The TPC value was 126.5 mg GA 100 g⁻¹ fw at the beginning of storage, 119.6 (10 °C, C) to 172.0 mg GA 100 g⁻¹ fw (0 °C, 1 mM OA) on day 2, and 198.7 (10 °C, C) to

207.6 mg GA 100 g⁻¹ fw (0 °C, 1 mM OA) at the end of storage on day 10. The highest increase was detected in the OA group samples stored at 0 °C (Figure 3A), and the effects of treatments on the TPC were statistically ($p < 0.05$) significant (Table 1).

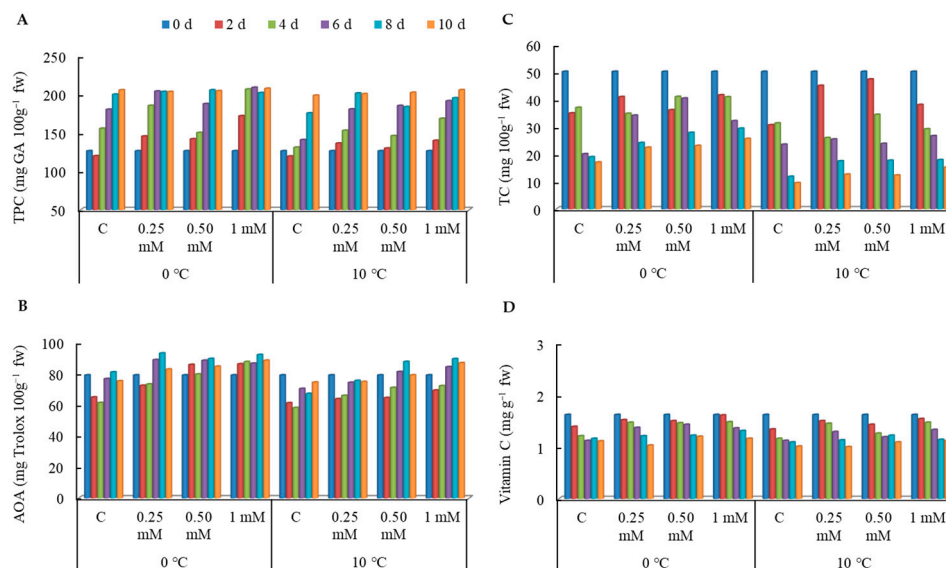


Figure 3. The effects of different OA treatments and storage temperatures on the total phenolic content (TPC) (A), antioxidant activity (AOA) (B), total chlorophyll content (TC) (C), and vitamin C (D) of rocket leaves in MAP during storage. C: Control, d: days.

Similar to the TPC values, the AOA values of rocket leaves fluctuated during storage; however, in general, they increased at the end of storage. The highest increases were detected in the OA-treated groups. The initial value measured as 79.0 mg 100 g⁻¹ fw was between 74.4 (10 °C, C) and 88.4 mg 100 g⁻¹ fw (0 °C, 1 mM OA) at the end of storage. OA applications were especially influential in terms of the preservation of AOA at 0 °C (Figure 3B). In studies conducted in different species, exogenously applied OA was reported to protect membrane integrity by preventing oxidation of phenolic substances and lipid peroxidation and increasing AOA [36,39,40].

3.4. Vitamin C and Total Chlorophyll Content

The total chlorophyll content of the rocket leaves decreased steadily throughout storage in all treatments and at both storage temperatures. The initial TC value measured as 50.2 mg 100 g⁻¹ fw was between 17.1 mg 100 g⁻¹ fw (C) and 25.7 mg 100 g⁻¹ fw (1 mM OA) at 0 °C and between 9.5 mg 100 g⁻¹ fw (C) and 15.3 mg 100 g⁻¹ fw (1 mM OA) at 10 °C at the end of storage (Figure 3C). Chlorophylls are color pigments responsible for the formation of green color in horticultural crops. It has been reported that chlorophyll levels decrease significantly with ripening, and applications that accelerate ripening (such as high temperature) also accelerate chlorophyll breakdown [41]. This is supported by the fact that the chlorophyll content of rocket leaves stored at high temperatures (10 °C) was lower than those stored at cold temperatures (0 °C). The chlorophyll content of OA-treated rocket leaves was higher than the C groups at both storage temperatures. The breakdown of chlorophyll is slower, and the color remains greener in OA-treated rocket leaves (Figure 3C). Similarly, Kayashima and Katayama [42] have reported that OA, a natural antioxidant substance, plays a vital role in preventing/slowing down oxidation events, and Cefalo and Pace [19] have reported that OA delays chlorophyll breakdown. The results obtained in the yellowing part were consistent with the chlorophyll content.

Vitamin C content decreased as the storage period progressed, regardless of the application and temperature. Vitamin C decreases rapidly or slowly after harvesting depending on species, variety, and environmental factors. As shown in Figure 3D, the

initial vitamin C content was 1.6 mg g⁻¹ fw and was determined to be between 1.2 (0 °C, 0.5 and 1 mM OA) and 1.0 mg g⁻¹ fw (0 °C: 0.25 mM OA, 10 °C: C and 0.25 mM) at the end of storage on day 10. Vitamin C content decreased at the end of storage, but no significant differences were observed between the treatments. This was associated with the preservation of rocket leaves under MAP conditions. MAP may have delayed the oxidation of vitamin C in all treatments by regulating the permeability of oxygen and carbon dioxide in it, and vitamin C can also be easily affected by many factors such as temperature, light, and the presence of oxygen, so the responses of rocket leaves to the treatments in terms of changes in vitamin C content may be different.

3.5. Indicator Statistics and Principal Component Analysis (PCA)

In the study, it was observed that many factors interact with each other to impact quality of rocket leaves during storage, so a correlation analysis study is needed. Figure 4 showed the correlation analysis results of the quality parameters of rocket leaves for the test. As expected, in terms of the analyzed parameters, a highly positive correlation was generally determined between samples stored at 0 °C and 10 °C. The highest significant negative correlation ($r: -0.98; p < 0.001$) was identified between EE (10 °C) and yellowing values (0 °C and 10 °C), while the highest significant positive correlation ($r: 0.99; p < 0.001$) value was identified between YY (0 °C) and YY (0 °C).

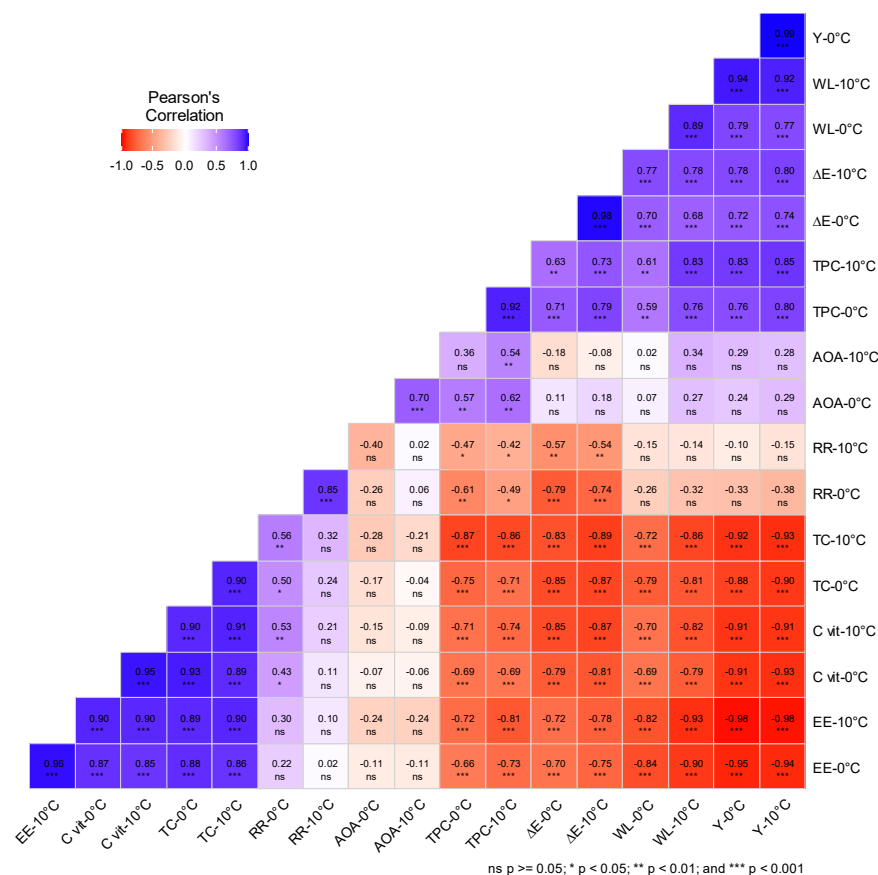


Figure 4. Correlation matrix of the parameters measured in rocket leaves. EE: External appearance, TC: Total chlorophyll content, C vit: Vitamin C, RR: Respiration rate, WL: Weight loss, Y: Yellowing, ΔE: Discoloration (color changes), TPC: Total phenolic content, AOA: Antioxidant activity.

KMO and Bartlett tests were performed on the original variables of the indicators of all samples of rocket leaves. The test results were shown in Table 2. The KMO value was 0.729 in Table 2, indicating that the data were suitable for factor analysis. The probability of

Bartlett's test statistical value was 0.000, and it was less than 0.05, which indicated that the data were correlated and could be used for factor analysis [43].

Table 2. Correlation test of KMO and Bartlett.

Test Method	KMO Measure of Sampling Adequacy	Bartlett's Test of Sphericity		
		Approx. χ^2	df	Sig.
Result	0.729	799.058	153	0.000

The squares of the coordinates (cos2) provide a measure of how well the major component expresses the relevant variable. Cos2 can be used to represent these values. The correlations between the variables and principal components are another way to express these values. The first principal component explains 68% of the variance, and the second principal component explains 12.5%. The squares of the coordinates (cos2) are an indicator of how successfully the variable of interest is represented by the principal component and is expressed as cos2. These values are also expressed as correlations between variables and principal components. When the vector directions of the properties were examined, it was seen that EE, C vit, TC, and RR exhibited negative correlations with the other properties. Among the properties that were examined, AOA had the lowest cos2 value and was considered to have the lowest effect on the principal components (Figure 5).

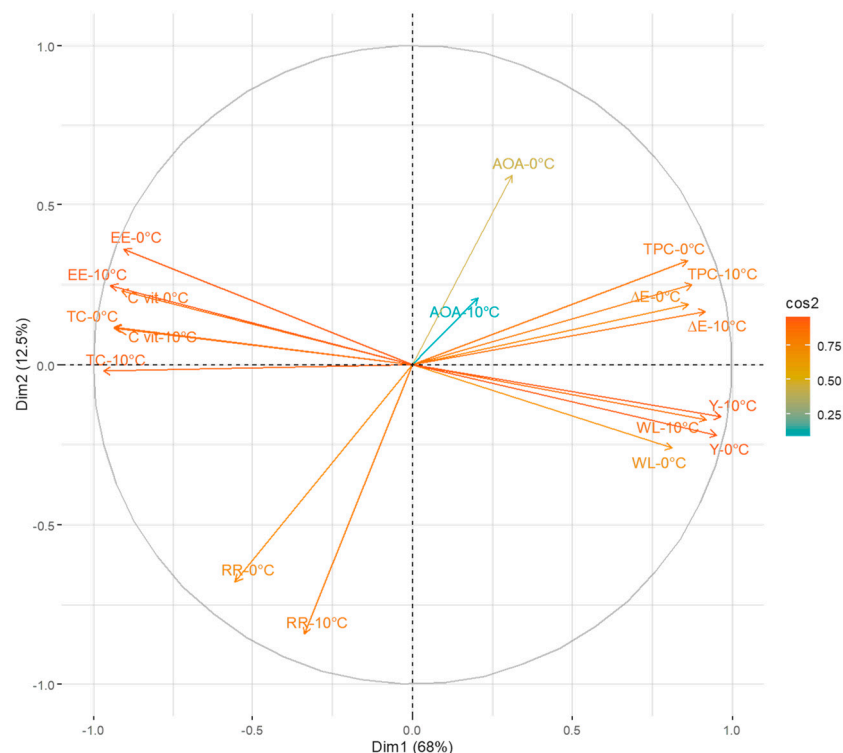


Figure 5. Principal component analysis (PCA) of the parameters measured in rocket leaves. EE: External appearance, TC: Total chlorophyll content, C vit: Vitamin C, RR: Respiration rate, WL: Weight loss, Y: Yellowing, ΔE : Discoloration (color changes), TPC: Total phenolic content, AOA: Antioxidant activity.

4. Conclusions

In this study, in which the effects of OA applied after harvesting on the quality of rocket leaves stored at different temperatures were examined, all doses of OA were effective in preserving the quality compared to the control treatment at both storage temperatures. In particular, weight loss and respiration rate were very low in OA-treated rocket leaves. The respiration rate, yellowing, and color change, an indicator of ripening, were low;

therefore, chlorophyll breakdown was also delayed in OA-treated rocket leaves. Vitamin C loss was also relatively lower in OA-treated rocket leaves compared to the untreated control group. The post-harvest quality of rocket leaves preserved by OA treatment under MAP conditions was maintained longer than the untreated group. In particular, 1 mM OA doses were the most effective treatment in terms of quality preservation at both storage temperatures. Considering the yellowing scores, which are very important for vegetables, it was determined that the rocket leaves cv. Bengi could be stored at 0 °C for 8–9 days with 1 mM OA treatment (2.67 score, 8th day) and 6 days with C treatment (2.83 score, 6th day) and at 10 °C for 6–7 days with 1 mM OA treatment (2.17 score, 6th day) and 4 days with C treatment (2.33 score, 4th day) with a minimum quality loss under MAP conditions. In conclusion, OA application is considered to be an effective application for the preservation of the post-harvest quality of rocket leaves. However, since the effects of such post-harvest applications can be affected by many factors, including variety, harvest time, application dose, application time, storage time, and storage condition, further studies with different varieties and species are needed.

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Conflicts of Interest: The author declares no conflict of interest.

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