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INFLUENCE OF TAP AND HOT WATER TREATMENT BEFORE SHORT-TERM STORAGE ON BIOLOGICALLY ACTIVE COMPOUNDS AND SENSORY QUALITY OF WILD ROCKET LEAVES (*DIPLOTAXIS TENUIFOLIA* L.)

Short communication

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ABSTRACT

The aim of this study was to determine the influence of dipping in tap and hot water (53 or 55 °C) before storage and conditions during short-term storage: 4 days at 18–20 °C temperature or 7 days at 0 or 5 °C, on contents of total polyphenols, ascorbic acid, antiradical activity, and sensory quality of leaves of wild rocket (*Diplotaxis tenuifolia* L.). The highest sensory values, ascorbic acid contents, and antiradical activity were found in fresh leaves. Treatments with tap and hot water before storage reduced ascorbic acid contents and antiradical activity, as well as most sensory parameters regardless of storage conditions. The highest overall quality of wild rocket after storage for 4 days at 18–20 °C was found for leaves not dipped or dipped in tap water. Dipping of the wild rocket in the water at 53 or 55 °C for 3 or 5 s did not improve the overall quality of stored leaves compared with leaves not dipped or dipped in tap water.

Keywords: ascorbic acid, polyphenols, antiradical activity, taste, flavor

INTRODUCTION

The requirements for fresh-cut horticulture products arise from consumers' desire to gain access to healthy and "ready to eat" food (Kaur & Kapoor 2001). After minimal processing, the quality characteristics of fruits and vegetables are not significantly changed and that is why they are similar to fresh produce. One of the important problems limiting the sale of minimally processed vegetables is their poor storability. The minimally processed vegetables are characterized by wilting and yellowing, due to chlorophyll degradation during their postharvest storage.

To prolong the storage ability of horticulture products, the treatment with hot water at a temperature around 60 °C is often applied. Some investigations suggest that hot water treatment decreases respiration rate and ethylene production, inhibits ripening, and lowers contamination by pathogens (Lurie 1998; Fallik et al. 1999; Ferguson et al. 2000; Fallik & Ilic 2019). According to Lurie (1998) and Saltveit (1998), at high temperatures the formation of new proteins – heat shock proteins – takes place. This may contribute to the increase of resistance to stresses during storage, including biotic and abiotic diseases (Vlachonasios et al. 2001). Hot water treatment can cause internal damage including yellowing, flesh softening, and development of internal cavities. Szwejda-Grzybowska et al. (2016) and Glowacz et al. (2018) have found that the treatment of pepper fruit with hot water before short-time storage has affected the content of bioactive compounds and antioxidant properties.

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The treatment of pepper fruit with water at 55 °C for 12 s was favorable and caused lower losses of bioactive compounds and increase of antiradical activity than treatment with water at 45 °C for 10 min. Barbagallo et al. (2012) reported a reduction of ascorbic acid content and an increase of polyphenol contents during the storage of fresh-cut yellow and red sweet pepper fruit for 14 days at 4 °C.

The leaves of wild rocket (*Diplotaxis tenuifolia* L.) are often used for the preparation of mixed vegetable salads (Martínez-Sánchez et al. 2012). This vegetable contains several compounds having very important properties for human health, including vitamin C, carotenoids, fibers, polyphenols, and glucosinolates (Martínez-Sánchez et al. 2006a; Bell & Wagstaff 2014). Rocket leaves are usually packed in trays wrapped with polypropylene film or in bags containing a modified atmosphere. Avoiding of disinfection or sterilization processes for rocket leaves may result in increasing the quality of product and higher shelf life (Martínez-Sánchez et al. 2012). The keeping conditions may also affect the overall quality of rocket leaves (Koukounaras et al. 2009). Usually, the temperature of 0 °C is suggested for storage of this vegetable (Cantwell & Kasmire 2002; Siomos & Koukounaras 2007); however, it is often kept at 10 °C during transport and sale. The leaves of the rocket, similarly to other fresh vegetables, cannot be stored for a longer time due to yellowing of the leaves within 4–8 days, even at a temperature of 5 °C (Ferrante et al. 2004).

When shopping, consumers usually assess the quality of the product visually (Barrett et al. 2010). Péneau et al. (2009) sum up that vegetable freshness is judged by color, crispness, and the age of the product. The fresh rocket leaves should have uniform dark green color and crunchiness (Løkke et al. 2012; Martínez-Sánchez et al. 2006a). Sensory descriptive analysis is the suggested method to control the freshness of horticulture products (Løkke et al. 2012). Rocket leaves are characterized by a pungent flavor, which is due to the presence of glucosinolates and isothiocyanates (Bennett et al. 2006).

There are many reports describing the effects of different chemical sanitizers on the microbial growth of rocket salad (Cantwell & Kasmire 2002; Rodgers et al. 2004; Martínez-Sánchez et al. 2006b) or the effects of temperature regime or modified atmosphere packaging (MAP) technologies (Løkke et al. 2012, Spadafora et al. 2016). However, little information is available on the influence of postharvest hot water treatment of rocket leaves on their sensory quality. Løkke et al. (2012) found that the concentrations of oxygen and carbon dioxide combined with temperature and storage time had a high impact on the overall freshness of wild rocket. Martínez-Sánchez et al. (2006b) reported a positive effect of washing wild rocket using tap water, chlorine, ozonated water, lactic acid, acidified sodium chlorite, and peroxyacetic acid.

In the present study, the effect of tap or hot water treatment before short-term storage at cold or ambient temperature on nutritive quality and sensory parameters of the wild rocket leaves was investigated.

MATERIALS AND METHODS

The study object was leaves of wild rocket (*D. tenuifolia* L.). The plant material was obtained directly from a grower's farm. Directly after harvest, the injured leaves were removed or trimmed. Two factors were evaluated: prior treatment of leaves with water and storage conditions. The following treatments were studied: (1) fresh material not stored (control); (2) not dipped in tap water; (3) dipped in tap water; (4) dipped in hot water (53 °C) for 5 s; and (5) dipped in hot water (55 °C) for 3 s. After treatments, the leaves were dried in a stream of air using two Severin VL 8620 fans and were packed into polystyrene foam trays and placed into boxes lined with polyethylene film. Objects were stored at 0 or 5 °C for 7 days or at 18–20 °C for 4 days. The fresh and stored leaves were evaluated for contents of chosen chemical compounds and for sensory quality.

Instrumental analysis

The following chemical analyses were carried out. Dry matter was determined by the gravimetric method and drying up to 102 °C. The content of total polyphenols was determined by the spectrophotometric Folin–Ciocalteu method, using a spectrophotometer UviLine 9400 at wavelength 750 nm (Van der Sluis et al. 2002) and using catechin as a standard.

The content of L-ascorbic acid was determined with the 2,6-dichlorophenolindophenol titrimetric method (PN-A-04019:1998). Antiradical capacity was determined by the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method (Brand-Williams et al. 1995; Sánchez-Moreno et al. 2002). The results are expressed as the mean of three analytical replicates (n = 3).

The experiment was set up in four replications of 200 g of fresh leaves each. Statistical analysis was performed with STATISTICA v. 10 (StatSoft 2011) as a one-way analysis of variance separately for each temperature. The significant differences between means were determined at p = 0.05 by Tukey's test.

Sensory evaluation

Sensory evaluation of the treated and non-treated leaves of the wild rocket was performed in a laboratory by 10 experts, using the quantitative description analysis (QDA), according to ISO standards (PN-ISO 8589:1998.). They evaluated smell, texture, and taste. The eight quality attributes and overall sensory quality were assessed (Table 1). The evaluation for each descriptor was signed on non-structural lines, with min–max points (0 – low intensity to 10 – high intensity of impression). Two independent sessions were performed for each analysis. ANALSENS software was used to evaluate the results. The significance of differences between means was estimated using Tukey's honestly significant difference (HSD) test (p = 0.05).

RESULTS AND DISCUSSION

The experiments showed that the hot water treatment with both temperature variants (53 °C for 5 s and 55 °C for 3 s) had a significant influence on the content of L-ascorbic acid, total polyphenols, and antiradical activity. In this study, a reduction in the content of L-ascorbic acid was observed at each storage temperature compared with the control. The highest decrease in the content of L-ascorbic acid was noted during storage at 18–20 °C for 4 days than during storage at 0 and 5 °C for 7 days, compared with the fresh material (control). The treatment with hot water at a temperature of 55 °C for 3 s was less detrimental as it caused lower losses of L-ascorbic acid than the treatment with a temperature of 53 °C for 5 s at each storage temperature. Higher content of total polyphenols in leaves was also observed in samples treated with water at 55 °C for 3 s than in the leaves treated at 53 °C for 5 s as compared with the control. Lower losses of total polyphenols were noted at 18–20 °C for 4 days compared with storage at 0 and 5 °C for 7 days. The antiradical capacity of wild rocket leaves stored at 18–20 °C for 4 days was lower compared with leaves stored at 0 or 5 °C, irrespective of parameters of hot water treatment. Higher antiradical activity was observed in leaves treated with water at 55 °C for 3 s than those treated at 53 °C for 5 s; however, these differences were not significant (Table 2).

Table 1. Definitions of sensory attributes used in the quantitative descriptive analysis

No.	Attribute	Agreed definition	Anchoring points
		Odor	
1	rocket-odor	characteristic odor of fresh rocket	undetectable – very intensive
2	off-odor	unusual odor for rocket	undetectable – very intensive
		Mouthfeel	
3	crispness	intensity of sound heard while biting the samples with the front teeth	no sound – very noisy
4	firmness	degree of force needed to chew the flesh	firm – soft
		Taste	
5	rocket taste	characteristic taste of fresh rocket	undetectable – very intensive
6	bitter taste	basic taste	undetectable – very intensive
7	pungent taste	impression of burning on tongue	undetectable – very intensive
		Flavor	
8	off-flavor	unusual flavor for rocket	undetectable – very intensive
9	overall quality	general sensory quality impression	low – high quality

There are limited reports on the influence of postharvest treatment on the bioactive substances and antiradical activity of rocket leaves. Most of the studies concern the ability of fresh-cut vegetables for short-term storage. Michalczyk and Macura (2008) reported the decrease of polyphenols, carotenoids, and ascorbic acid during storage of lamb's lettuce, arugula, and iceberg lettuce for 9 days at 0 and 6 °C. Koukounaras et al. (2009) found that the treatment of rocket leaves with water of 50 °C for 4 and 20 s and then short-term storage retarded yellowing. Extension of treatments to 30 s has increased ethylene production and extended their postharvest life at 8 °C from 5 to 10 days and did not reduce the postharvest quality. Gómez et al. (2008) observed that the treatment of spinach leaves with water of 40 °C for 3.5 min had a positive effect. It was found that the content of small heat shock proteins increased proportionally to the temperature applied, with undetectable levels in untreated leaves. The water treatment at 40 °C delayed leaf senescence as indicated by higher chlorophyll content and potential quantum yield of PSII (Fv/Fm) and decreased solute leakage after storage for 7 days, compared with untreated samples. Glowacz et al. (2013) reported that water treatment at 45 °C for 60 s has only limited potential to improve the quality of spinach leaves after and short-term storage in plastic bags at 4 °C. This treatment did not increase the shelf life, did not prolong the tissue quality, and did not change the ascorbic acid and carotenoid contents. The treatment of spinach leaves with water at 40 °C was only effective when the leaves were subsequently stored at 0 °C but not when storage was at 6 °C (Glowacz et al. 2018).

Table 2. The effect of hot water treatment and storage condition on the qualitative indices of wild rocket leaves

Treatment	Ascorbic acid (mg·100 g^{-1} d.m.)	Total polyphenols (mg·100 g^{-1} d.m.)	Antiradical activity (% DPPH)
After 4 days of storage at a temperature of 18–20 °C			
Fresh material not stored (control)	1106 ±1.54 a	1049 ± 1.76 b	38.9 ± 0.44 a
Not dipped in tap water	1020 ±1.33 b	1099 ± 3.88 a	30.6 ± 0.37 b
Dipped in tap water	953 ± 1.12 c	1063 ± 2.72 b	22.8 ± 0.24 c
Dipped in water of 53 °C; 5 s	681 ± 0.74 e	891 ± 1.34 d	16.7 ± 0.18 d
Dipped in water of 55 °C; 3 s	821 ± 1.14 d	992 ± 1.13 c	15.6 ± 0.33 d
After 7 days of storage at a temperature of 0 °C			
Fresh material not stored (control)	1106 ± 1.54 b	1049 ± 1.76 b	38.9 ± 0.44 a
Not dipped in tap water	1148 ± 1.17 a	1082 ± 2.26 a	36.3 ± 0.37 a
Dipped in tap water	996 ± 1.10 c	1035 ± 1.63 b	29.9 ± 0.25 b
Dipped in water of 53 °C; 5 s	924 ± 0.92 d	944 ± 1.78 d	24.9 ± 0.27 c
Dipped in water of 55 °C; 3 s	1021 ± 0.87 c	1007 ± 2.94 c	30.8 ± 0.36 b
After 7 days of storage at a temperature 5 °C			
Fresh material not stored (control)	1106 ± 1.54 a	1049 ± 1.76 b	38.9 ± 0.44 a
Not dipped in tap water	983 ± 1.66 b	1122 ± 2.56 a	31.5 ± 0.25 b
Dipped in tap water	914 ± 0.75 c	1119 ± 2.16 a	30.3 ± 0.27 b
Dipped in water of 53 °C; 5 s	876 ± 1.34 d	955 ± 3.12 c	27.6 ± 0.33 b
Dipped in water of 55 °C; 3 s	975 ± 0.83 b	1037 ± 2.25 b	29.6 ± 0.27 b

Means in the column for each storage temperature marked with the same letter are not different according to Tukey's HSD test (p = 0.05)

Table 3. The effect of hot water treatment and storage condition on sensory analysis of wild rocket leaves (intensity scale: 0–10)

Treatment	Quality descriptors								
	rocket smell	off-odor	crispness	firmness	rocket taste	bitter taste	pungent taste	off-flavor	overall quality
After 4 days of storage at a temperature of 18–20 °C									
Fresh material not stored (control)	5.0 a	0 d	7.0 a	7.1 a	8.0 a	4.0 a	5.2 a	0 c	7.5 a
Not dipped in tap water	4.2 a	0.8 c	6.9 a	7.1 a	7.7 a	3.2 a	4.4 b	0 c	7.1 a
Dipped in tap water	2.6 b	2.2 b	6.7 a	6.5 a	7.4 a	3.5 a	3.4 b	0.1 b	6.9 a
Dipped in water of 53 °C; 5 s	2.7 b	3.7 a	6.7 a	6.3 a	5.4 b	3.5 a	2.2 c	1.6 a	5.1 b
Dipped in water of 55 °C; 3 s	3.1 b	3.5 a	6.3 a	6.4 a	6.4 b	3.4 a	2.5 c	1.2 a	5.2 b
After 7 days of storage at a temperature of 0 °C									
Fresh material not stored (control)	5.0 a	0 d	7.0 a	7.1 a	8.0 a	4.0 b	5.2 a	0	7.5 a
Not dipped in tap water	4.2 a	1.1 bc	6.4 a	6.3 a	6.6 b	7.1 a	2.9 c	0	7.3 a
Dipped in tap water	3.7 b	2.0 a	7.0 a	6.5 a	6.5 b	6.6 ab	4.2 b	0	6.5 b
Dipped in water of 53 °C; 5 s	3.2 b	1.7 b	6.7 a	6.2 a	6.7 b	7.5 a	3.1 c	0	6.9 ab
Dipped in water of 55 °C; 3 s	2.8 bc	2.8 a	6.7 a	5.8 b	6.1 b	6.9 a	3.5 c	0	6.4 b
After 7 days of storage at a temperature of 5 °C									
Fresh material not stored (control)	5.0 a	0 b	7.0 a	7.1 a	8.0 a	4.0 a	5.2 a	0 a	7.5 a
Not dipped in tap water	2.9 c	0.2 b	6.5 a	7.3 a	7.0 b	2.5 b	3.3 b	0 a	7.0 a
Dipped in tap water	3.7 b	0.5 b	6.6 a	6.8 a	6.9 b	2.8 b	2.9 b	0 a	7.2 a
Dipped in water of 53 °C; 5 s	3.4 b	2.4 a	6.7 a	7.0 a	6.2 b	3.5 a	2.9 b	0.02 a	6.5 b
Dipped in water of 55 °C; 3 s	3.5 b	1.9 a	6.3 a	6.6 a	6.5 b	3.5 a	3.4 b	0 a	6.2 b

Note: see Table 2

Løkke et al. (2012) reported differences in sensory quality between samples of wild rocket leaves stored at atmosphere differing in concentrations of oxygen and carbon dioxide and an interaction of atmosphere with storage temperature (2, 10 and 20 °C). In our results, storage temperature influenced the sensory quality of wild rocket leaves (Table 3). The fresh leaves of the wild rocket were characterized by better overall quality compared with material treated with hot water and stored. Overall quality characteristic is based on notes for all sensory quality attributes and summarizes the quality impression of the evaluated sample. In this study, the highest overall quality was found in fresh leaves and those not dipped in water or dipped in tap water regardless on storage condition. Fresh wild rocket leaves were characterized by a higher intensity of smell typical for the rocket, higher crispness and firmness, more intensive taste, higher intensity of pungent and characteristic bitter taste, compared with samples treated with hot water and stored. The evaluation did not show the off-odor and off-flavor presence in leaves of the wild rocket after harvest (Table 3). After storage, the typical smell and taste of the rocket leaves decreased compared with the fresh material. Pungent taste characteristic for the wild rocket, but not desirable in a high amount, was rated on a low level for all stored samples regardless of kind of treatment. The bitter and pungent taste of rocket leaves may result from glucosinolates and phenolics accumulated in the leaves (Nielsen et al. 2008; Bell et al. 2017). Leaves rich in these compounds can be rated as having a stronger flavor. Crispness and firmness were also affected by storage temperature. Crispness and firmness were not affected by water treatments with one exception when hot water at 55 °C and storage for 7 days decreased firmness. Off-odor described as rotten and spoiled was produced under hot water treatment, especially after storage at room temperature. Control leaves were characterized by higher texture, lowest intensity of spoiled smell, and by the highest scores of overall quality.

CONCLUSIONS

1. The highest sensory values had fresh wild rocket leaves. The antiradical activity was also the highest in fresh leaves not dipped in tap water and stored at 0 and 5 °C or room temperature. After storage, the antiradical activity of rocket leaves decreased. Total polyphenol contents increased as a result of storage without any prior treatment or dipped in tap water when leaves were stored at room temperature and at 5 °C.
2. Treatments with tap or hot water before short-term storage generally reduced ascorbic acid content, antiradical activity, and most sensory parameters, regardless of the storage conditions.
3. Dipping of the wild rocket leaves in the water at 53 or 55 °C for 3 or 5 s did not improve the overall quality of stored leaves compared with leaves not dipped or dipped in tap water.
4. Dipping in the water before storage regardless of storage temperature did not affect the firmness and crispness of leaves but decreased the rocket smell and taste and increased off-odor and off-flavor, especially after storage at room temperature.

REFERENCES

Barbagallo R., Chisari M. Patané C. 2012. Polyphenol oxidase total phenolics and ascorbic acid changes during storage of minimally processed ‘California Wonder’ and ‘Quadrato d'Asti’ sweet peppers. LWT – Food Science and Technology 49 (2): 192–196. DOI: 10.1016/j.lwt.2012.06.023.

Barrett D.M., Beaulieu J.C., Shewfelt R. 2010. Color, flavor, texture, and nutritional quality of fresh-cut fruits and vegetables: desirable levels, instrumental and sensory measurement, and the effects of processing. Critical Reviews in Food Science and Nutrition 50: 369–389. DOI: 10.1080/10408391003626322.

Bell L., Methven L., Signore A., Oruna-Concha M.J., Wagstaff C. 2017. Analysis of seven salad rocket (*Eruca sativa*) accessions: the relationship between sensory attributes and volatile and non-volatile compounds. Food Chemistry 218: 181–191. DOI: 10.1016/j.foodchem.2016.09.076.

Bell L., Wagstaff C. 2014. Glucosinolates, myrosinase hydrolysis products, and flavonols found in rocket (*Eruca sativa* and *Diplotaxis tenuifolia*). Journal of Agricultural and Food Chemistry 62(20): 4481–4492. DOI: 10.1021/jf501096x.

Bennett R., Rosa E.A.S., Mellon F.A., Kroon P.A. 2006. Ontogenic profiling of glucosinolates, flavonoids, and other secondary metabolites in *Eruca sativa* (salad rocket), *Diplotaxis erucoides* (wall rocket), *Diplotaxis tenuifolia* (wild rocket), and *Bunias orientalis* (Turkish rocket). Journal of Agricultural and Food Chemistry 54(11): 4005–4015. DOI: 10.1021/jf052756t.

Brand-Williams W., Cuvelier M.E., Berset C. 1995. Use of a free radical method to evaluate antioxidant activity. LWT – Food Science and Technology 28: 25–30. DOI: 10.1016/s0023-6438(95)80008-5.

Cantwell M.I., Kasmire R.F. 2002. Postharvest handling systems: flower, leafy, and stem vegetables. Postharvest technology of horticultural crops. In: Kader AA. (Ed.), Postharvest technology of horticultural crops. University of California, pp. 423–433.

Fallik E., Grinberg S., Alkalai S., Yekutieli O., Wiseblum A., Regev R. et al. 1999. A unique rapid hot water treatment to improve storage quality of sweet pepper. Postharvest Biology and Technology 15(1): 25–32. DOI: 10.1016/s0925-5214(98)00066-0.

Fallik E., Ilic Z. 2019. Positive and negative effects of heat treatment on the incidence of physiological disorders in fresh produce. In: Tonetto de Freitas S., Pareek S. (Eds.), Postharvest Physiological Disorders in Fruits and Vegetables. CRC Press, pp. 111–126. DOI: 10.1201/b22001-6.

Ferrante A., Incrocci L., Maggini R., Serra G., Tognoni F. 2004. Colour changes of fresh-cut leafy vegetables during storage. Journal of Food, Agriculture and Environment 2: 40–44. DOI: 10.1234/4.2004.250.

Ferguson I.B., Ben-Yehoshua S., Mitcham E.J., McDonald R.E., Lurie S. 2000. Postharvest heat treatments: introduction and workshop summary. Postharvest Biology and Technology 21(1): 1–6. DOI: 10.1016/s0925-5214(00)00160-5.

Glowacz M., Mogren L.M., Reade J.P.H., Cobb A.H., Monaghan J.M. 2013. Can hot water treatments enhance or maintain postharvest quality of spinach leaves? Postharvest Biology and Technology 81: 23–28. DOI: 10.1016/j.postharvbio.2013.02.004.

Glowacz M., Reade J., Monaghan J., Mogren L. 2018. Hot water treatment after harvest preserves nutritional quality of spinach during storage. Acta Horticulturae 1209: 123–128. DOI: 10.17660/actahortic.2018.1209.18.

Gómez F., Fernández L., Gergoff G., Guiamet J.J., Chaves A., Bartoli C.G. 2008. Heat shock increases mitochondrial H_2O_2 production and extends postharvest life of spinach leaves. Postharvest Biology and Technology 49(2): 229–234. DOI: 10.1016/j.postharvbio.2008.02.012.

Kaur Ch., Kapoor H.C. 2001. Antioxidants in fruits and vegetables – the millennium's health. International Journal of Food Science and Technology 36: 703–725. DOI: 10.1111/j.1365-2621.2001.00513.x.

Koukounaras A., Siomos A.S., Sfakiotakis E. 2009. Impact of heat treatment on ethylene production and yellowing of modified atmosphere packaged rocket leaves. Postharvest Biology and Technology 54: 172–176. DOI: 10.1016/j.postharvbio.2009.07.002.

Løkke M.M., Seefeldt H.F., Edelenbos M. 2012. Freshness and sensory quality of packaged wild rocket. Postharvest Biology and Technology 73: 99–106. DOI: 10.1016/j.postharvbio.2012.06.004.

Lurie S. 1998. Postharvest heat treatments. Postharvest Biology and Technology 14(3): 257–269. DOI: 10.1016/s0925-5214(98)00045-3.

Martínez-Sánchez A., Marín A., Llorach R., Ferreres F., Gil M.I. 2006a. Controlled atmosphere preserves quality and phytonutrients in wild rocket (*Diplotaxis tenuifolia*). Postharvest Biology and Technology 40: 26–33. DOI: 10.1016/j.postharvbio.2005.12.015.

Martínez-Sánchez A., Allende A., Bennett R.N., Ferreres F., Gil M.I. 2006b. Microbial. nutritional and sensory quality of rocket leaves as affected by different sanitizers. Postharvest Biology and Technology 42: 86–97. DOI: 10.1016/j.postharvbio.2006.05.010.

Martínez-Sánchez A., Luna M.C., Selma M.V., Tudela J.A., Abad J., Gil M.I. 2012. Baby-leaf and multi-leaf of green and red lettuces are suitable raw materials for the fresh-cut industry. Postharvest Biology and Technology 63: 1–10. DOI: 10.1016/j.postharvbio.2011.07.010.

Michalczyk M., Macura R. 2008. Effect of storage conditions on the quality of some selected low processed vegetable products available in the markets. Żywność. Nauka. Technologia. Jakość 3(58): 96–107. [in Polish with English abstract]

Nielsen T., Bergström B., Borch E. 2008. The origin of off-odours in packaged rucola (*Eruca sativa*). Food Chemistry 110: 96–105. DOI: 10.1016/j.foodchem.2008.01.063.

Péneau S., Linke A., Escher F., Nuessli J. 2009. Freshness of fruits and vegetables: consumer language and perception. British Food Journal 111: 243–256. DOI: 10.1108/00070700910941453.

PN-A-04019:1998. Produkty spożywcze. Oznaczanie zawartości witaminy C.

PN-ISO 8589:1998. Analiza sensoryczna. Ogólne wytyczne projektowania pracowni analizy sensorycznej.

Rodgers S.L., Cash J.N., Siddiq M., Ryser E.T. 2004. A comparison of different chemical sanitizers for inactivating *Escherichia coli* O157:H7 and *Listeria monocytogenes* in solution and on apples, lettuce, strawberries, and cantaloupe. Journal of Food Protection 67: 721–731. DOI: 10.4315/0362-028x-67.4.721.

Saltveit M.E. 1998. Heat-shock and fresh cut lettuce. Perishables Handling Quarterly 95: 5–6.

Sánchez-Moreno C. 2002. Methods used to evaluate the free radical scavenging activity in foods and biological systems. Food Science and Technology International 8: 121–137. DOI: 10.1106/108201302026770.

Siomos A.S., Koukounaras A. 2007. Quality and postharvest physiology of rocket leaves. Fresh Produce 1(1): 59–65.

Van der Sluis A.A., Dekker M., Skrede G., Jongen W.M.F. 2002. Activity and concentration of polyphenolic antioxidants in apple juice. 1. Effect of existing production methods. Journal of Agricultural and Food Chemistry 50 (25): 7211–7214. DOI: 10.1021/jf020115h.

Spadafora N.D., Amaro A.L., Pereira M.J., Müller C.T., Pintado M., Rogers H.J. 2016. Multi-trait analysis of post-harvest storage in rocket salad (*Diplotaxis tenuifolia*) links sensorial, volatile and nutritional data. Food Chemistry 211: 114–123. DOI: 10.1016/j.foodchem.2016.04.107.

StatSoft 2011. STATISTICA. Data analysis software system, v. 10. www.statsoft.com

Szwejda-Grzybowska J., Kosson R., Grzegorzewska M. 2016. The effect of short-term storage and the hot water treatment of fresh-cut pepper fruit cv. 'Blondy F_1'

and 'Yecla F_1' on the content of bioactive compounds and antioxidant properties. Journal of Horticultural Research 24(2): 83–90. DOI: 10.1515/johr-2016-0024.

Vlachonasios K.E., Kadyrzhanova D.K., Dilley D.R. 2001. Heat treatment prevents chilling injury of tomato (*Lycopersicon esculentum*) fruits: heat shock genes and heat shock proteins in the resistance of tomato fruit to low temperatures. Acta Horticulturae 533: 543–547. DOI: 10.17660/actahortic.2001.553.126.