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Investigation of Changes in Color and Textural Quality Characteristics of Arugula (*Eruca vesicaria*) by Disinfectant Treatments

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A B S T R A C T

The aim of this study was to investigate the effects of the treatment of tap water (control), sodium hypochlorite (SH), electrolyzed oxidizing water (EOW), and hydrogen peroxide (HP) on the color, texture, and sensory properties of the *Eruca vesicaria* as a quality criterion. For this purpose, three different concentrations (25, 50, and 75 ppm) and three different times (1, 3, and 5 min) were applied in all three washing processes. There weren't statistically significant differences in objective (color and texture) and subjective (sensory) results in all three washing processes in terms of both concentration and time. Thus, it was determined that these processes did not have a negative effect on the quality of green leafy vegetables.

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Introduction

Nowadays, there is a rising demand for minimally processed fruits and vegetables, particularly in industrialized countries. These products, which are closest to their freshness, satisfy consumers' demand to consume healthy food. Minimally processed products are also very attractive for catering companies. In these companies, these products are preferred because they reduce the current workforce, save time, and reduce costs (Türkmen and Sar, 2004). The minimal treatment of fruits and vegetables gets applied, such as cleaning, cutting, slicing, washing, drying, and packaging immediately after harvesting (King et al., 1991; Guidi et al., 2007). With these processes, it is aimed to reduce the microbial load of the product and to keep the quality parameters of the product such as color and texture. There are many studies on the use and determining the effects of these disinfectants on various fruits and vegetables (İzumi, 1999; Baydar, 2007; Guan et al, 2013; Bermudez-Aguirre and Barbosa-Canovas, 2013; Pazır et al., 2008; Barut Gök and Pazır, 2019; Park et al., 2001). However, studies generally aim to reduce the microbial load. In some studies that examined the quality parameters, the difference wasn't found in the fruit and vegetables depending on the time and the concentration of the chemicals used, (Chen et al., 2020; Liu et al., 2019; Guan et al., 2013), while in some studies the difference was found to be statistically significant (Barut Gök and Pazır., 2019; Bermudez-Aguirre and Barbosa-Canovas, 2013). In several studies with chlorine and electrolyzed oxidizing water (EOW), there was no significant difference in the color and texture of spinach, mashroom, and carrots in terms of time and concentration (Izumi, 1999; Pazır et al., 2008; Guan et al., 2013). Also, in another study with EOW, there was no difference in the color of spinach, grapes, and fresh beans (Qi et al., 2018). However, in another study with chlorine, the difference was found to be significant in color (Bermudez-Aguirre and Barbosa-Canovas, 2013). In a study with clorine and EOW, while time was not found to be important, concentration was found to be important (Baydar, 2007). In another study, while 1% hydrogen peroxide application did not have a significant effect on the texture of red pepper, the effect of 5% hydrogen peroxide application was found to be significant (Alexandre et al., 2012). Today, it is known that the demand for minimally processed foods is increasing. But consumers want to consume good products not only in microbiological terms but also in quality. In our previous study, the effects of these disinfectants on total aerobic bacteria were investigated under the same conditions (Hossein Zadeh and Pazır, 2016). However, it has been noticed that there are few studies on quality parameters. Thus, the purpose of this study is to investigate the change in color, texture, and sensory properties of the *Eruca vesicaria* after being treated with sodium hypochlorite, EOW, and hydrogen peroxide.

Materials and methods

Materials

The *Eruca vesicaria* that was used in the experiments was provided daily and fresh from a local manufacturer in İzmir (Türkiye). *Eruca vesicaria* was brought to the Ege University, Engineering Faculty, Food Engineering Department laboratory as soon as possible and kept at 4°C until the experiments began.

Methods

Preparation of Chlorine Water

Chlorine solutions (Merck) with an active chlorine content of 25 ppm, 50 ppm, and 75 ppm were prepared from sodium hypochlorite with an active chlorine content of 13%.

Preparation Electrolyzed Oxidizing Water

Electrolyzed oxidizing water was produced with the ROX 20 TB-U Model (Hoshizaki Electric Co., Ltd., Japan) EOW generator. The EOW generator was supplied with a saline (NaCl) water solution at a concentration of 13 to 15% prepared with deionized water at 2 bar pressure. The standard feature of water outlet (ACC: 80 ppm, pH 2.7; ORP: 1100 mV) is attained thirty minutes after the generator was started to bring the amperage to stability (Barut Gök and Pazır., 2019).

Preparation of Hydrogen Peroxide

Hydrogen peroxide solutions (Merck) with active hydrogen peroxide content of 25 ppm, 50 ppm and 75 ppm were prepared from hydrogen peroxide with active hydrogen peroxide content of 35%.

Pretreatments Applied to Eruca Vesicaria

Eruca vesicaria was pre-washed with tap water and then removed unsuitable leaves (yellowed, rotten, crushed, etc.). Sodium hypochlorite, EOW and hydrogen peroxide in three different concentrations (25 ppm, 50 ppm and 75 ppm) and tap water for control were used in the washing processes (20°C). After placing the *Eruca vesicaria* in 1-liter jars, 500 mL of washing solution is added over them. The washing solution was removed after the specified time. Then, it was kept on filter paper for about 20 minutes at a laboratory temperature to remove the water. Then, color, texture, and sensory analysis were carried out.

Color Measurement

Colorimetric measurements of the samples were realized using a spectrophotometer (Model CM-508-d, Minolta, Japan). The color values were expressed as the CIE L*, a*, and b* (Brenes et al., 1995). L * is the brightness, a * is the green coordinate, and b * is the yellow coordinate. An increase in the L * value indicates a brighter sample. While the decrease in the a* value indicates a lighter green, the increase in the b * value indicates an increase in the degree of yellowness in *Eruca vesicaria*, which is not desired. Ten different readings were performed to represent the sample. The inner surface of the leaves was placed in the reading area.

Texture Measurement

Texture analysis was performed by the TA XT Plus Texture Analyzer (Stable Micro Systems) with the A/LKB precision blade set (Alexandre et al., 2012). One leaf of *Eruca vesicaria* from each sample was placed on the heavy-duty platform. The test speed and distance were set at 5 mm/s and 38 mm, respectively.

Sensory Analysis

The sensory analysis of samples was done by using the scoring test technique. For this purpose, 8 trained panelists were used. Panelists were trained on the sensory quality characteristics of fresh *Eruca vesicaria*. The panels were carried out with 2 repetitions for each sample. Panelists evaluated the color, surface texture, and smell characteristics of the samples by using the scoring test that was developed during the training stage. Color and surface texture were scored on a 5-point scale, whereas smell was scored on a 3-point scale (Altuğ and Elmaci, 2011).

Statistical Analysis

Trials were performed in two repetitions and three parallel. According to this, the SPSS 9.0 for Windows (SPSS 1999 Versiyon 9.0. Chicago, IL, USA) package program was used to analyze the variance and Duncan Multiple Test with 95% confidence.

Result and discussion

Changes in Color Values

The L*, a*, and b* values of the color variable, which is the quality criterion, are shown in Table. 1. There was no significant difference in L*, a* and b* values after washing with chlorinated water, EOW or hydrogen peroxide compared to the control. When all three washing processes (sodium hypochlorite, EOW and hydrogen peroxide) were evaluated individually, no statistically significant difference was found in terms of washing time and concentration ($P \geq 0.05$).

In the study by Izumi (1999), chopped carrot, spinach, and radish samples washed with chlorine solutions and EOW (15, 30, 50 ppm) were examined in terms of color. There was no change in L* (luminous), a* (green) and b* (yellowness) values. The results of this study were in agreement with our findings. Park et al. (2001) stated that there was no change in color of lettuce after the washing process with acidified chlorinated water and EOW, and after storage for 14 days at 4°C. In another study with tap water, chlorinated water, and EOW, there was no statistically significant difference in L*, a*, and b* values in terms of time (1, 5, and 10 min). However, a significant difference was found in a* value in terms of chlorine concentration (15, 30 and 50 ppm) (Baydar, 2007). Treatment of mushrooms with 3% hydrogen peroxide or a combination of hydrogen peroxide and UV-C (0.45 kJ/m^2 for 15 s) and storage at 4°C for 14 days did not cause a statistically significant change in L*, a* and b* values (Guan et al., 2013).

Table 1. *L**, *a**, *b**, and hardness values of *Eruca vesicaria* treated with tap water (control), sodium hypochlorite (SH), electrolyzed oxidizing water (EOW) and hydrogen peroxide (HP)

Treatment	Time (min)	*L**	*a**	*b**	Hardness (g)
Tap water	1	48.03±0.09[a1]	-17.91±1.13[a1]	27.03±0.12[a1]	930.63±77.37[a1]
Tap water	3	48.05±0.11[a1]	-17.97±1.27[a1]	27.05±0.05[a1]	931.89±71.81[a1]
Tap water	5	47.98±0.13[a1]	-17.97±1.18[a1]	27.05±0.09[a1]	933.17±67.48[a1]
SH 25 ppm	1	47.65±0.57[a1]	-17.56±0.63[a1]	27.03±0.07[a1]	931.82±80.38[a1]
SH 25 ppm	3	47.78±0.67[a1]	-17.66±0.67[a1]	27.03±0.13[a1]	931.88±81.38[a1]
SH 25 ppm	5	47.61±0.63[a1]	-17.55±0.65[a1]	26.99±0.06[a1]	932.17±85.40[a1]
SH 50 ppm	1	47.82±0.83[a1]	-17.63±0.68[a1]	26.96±0.07[a1]	931.66±71.82[a1]
SH 50 ppm	3	47.82±0.79[a1]	-17.71±0.67[a1]	27.01±0.03[a1]	933.15±72.67[a1]
SH 50 ppm	5	47.81±0.84[a1]	-17.66±0.72[a1]	26.94±0.04[a1]	933.60±65.43[a1]
SH 75 ppm	1	47.88±0.85[a1]	-17.67±0.75[a1]	27.05±0.02[a1]	932.30±85.74[a1]
SH 75 ppm	3	47.77±0.89[a1]	-17.67±0.73[a1]	27.01±0.14[a1]	932.86±76.53[a1]
SH 75 ppm	5	47.90±0.83[a1]	-17.68±0.65[a1]	27.00±0.02[a1]	933.20±75.45[a1]
Tap water	1	46.82±0.79[a1]	-17.71±0.67[a1]	28.01±0.03[a1]	918.09±112.35[a1]
Tap water	3	46.81±0.98[a1]	-17.66±0.72[a1]	27.94±0.04[a1]	918.25±113.85[a1]
Tap water	5	46.89±1.00[a1]	-17.67±0.75[a1]	28.00±0.09[a1]	918.75±122.86[a1]
EOW 25 ppm	1	46.97±1.03[a1]	-17.67±0.73[a1]	27.46±0.63[a1]	918.34±122.47[a1]
EOW 25 ppm	3	46.82±0.94[a1]	-17.68±0.65[a1]	28.00±0.02[a1]	918.85±116.66[a1]
EOW 25 ppm	5	46.91±0.81[a1]	-17.75±0.67[a1]	27.93±0.01[a1]	919.16±120.83[a1]
EOW 50 ppm	1	46.78±0.85[a1]	-17.75±0.72[a1]	27.98±0.05[a1]	919.17±111.22[a1]
EOW 50 ppm	3	46.87±0.87[a1]	-17.76±0.70[a1]	27.97±0.00[a1]	919.60±114.25[a1]
EOW 50 ppm	5	46.75±0.72[a1]	-17.77±0.67[a1]	28.01±0.05[a1]	919.99±104.89[a1]
EOW 75 ppm	1	46.85±0.89[a1]	-17.78±0.72[a1]	27.98±0.03[a1]	920.18±123.69[a1]
EOW 75 ppm	3	46.79±0.74[a1]	-17.77±0.72[a1]	27.99±0.04[a1]	920.58±113.09[a1]
EOW 75 ppm	5	46.92±0.87[a1]	-17.63±0.67[a1]	27.98±0.04[a1]	920.67±110.03[a1]
Tap water	1	47.82±0.79[a1]	-18.16±0.60[a1]	27.01±1.37[a1]	883.59±148.17[a1]
Tap water	3	47.81±0.98[a1]	-18.06±0.86[a1]	27.44±0.66[a1]	882.73±162.66[a1]
Tap water	5	48.39±0.29[a1]	-17.97±0.61[a1]	27.05±1.38[a1]	882.56±157.18[a1]
HP 25 ppm	1	48.47±0.33[a1]	-17.92±0.80[a1]	27.01±1.27[a1]	882.59±160.76[a1]
HP 25 ppm	3	48.32±0.23[a1]	-17.88±0.94[a1]	27.50±0.73[a1]	882.58±161.25[a1]
HP 25 ppm	5	47.91±0.81[a1]	-17.85±0.53[a1]	27.08±0.65[a1]	882.50±159.29[a1]
HP 50 ppm	1	48.28±0.14[a1]	-17.90±0.50[a1]	27.10±0.75[a1]	882.76±152.80[a1]
HP 50 ppm	3	47.87±0.87[a1]	-17.96±0.41[a1]	27.09±0.77[a1]	881.91±157.07[a1]
HP 50 ppm	5	47.25±1.42[a1]	-17.92±0.46[a1]	27.06±0.69[a1]	881.81±159.67[a1]
HP 75 ppm	1	46.85±0.89[a1]	-18.03±0.36[a1]	27.04±0.71[a1]	881.23±153.32[a1]
HP 75 ppm	3	47.79±0.74[a1]	-17.92±0.50[a1]	27.15±0.71[a1]	881.13±149.21[a1]
HP 75 ppm	5	47.92±0.87[a1]	-17.88±0.32[a1]	26.88±0.32[a1]	880.83±142.86[a1]

Bermudez-Aguirre and Barbosa-Canovas (2013) investigated the differences in L*, a*, and b* values after a 15-minute washing process with 100 ppm chlorinated water. As a result of this study, a statistically significant difference was found in L* value compared to the control sample, while the change in a* and b* was not significant. In another study, there was no difference in color compared to the control in spinach, grapes, and fresh beans (120 mg/L EOW for 15 minutes) (Qi et al., 2018).

Changes in Texture Value

As seen in Table 1, no statistically significant difference was found between the samples. When all three washing processes (sodium hypochlorite, EOW and hydrogen peroxide) were evaluated individually, no statistically significant difference was found in terms of washing time and concentration ($P \geq 0.05$). Pazır et al. (2008) found no statistically significant difference in hardness between spinach washed with chlorinated water or EOW. The results of this study are similar to our study. As a result of hardness analysis of olives, after 1 minute of washing with chlorinated water and EOW, a statistical difference was found with tap water (Barut Gök and Pazır, 2019). Washing with 120 mg/L EOW for 15 minutes did not affect the texture of spinach, grapes and green beans (Qi et al., 2018). But EOW (48 ppm) treated blueberries were softer during storage compared to the tap water (Chen et al., 2019).

Sensory Analysis Results

Sensory quality data of the *Eruca vesicaria* is given in Table 2. According to sensory analysis, the difference in terms of time and concentration on the color, surface texture and smell characteristics of the *Eruca vesicaria* was not statistically significant as a result of washing with tap water, chlorinated water, EOW or hydrogen peroxide ($P \geq 0.05$). Although there are studies comparable to our study, there are very few studies on sensory evaluation. In a study, there wasn't a difference in color, smell, or taste between the unwashed tomatoes and treated tomatoes with EOW (30 ppm) (Bari et al., 2003).

Table 2. Sensory evaluation of *Eruca vesicaria* treated with tap water (control), sodium hypochlorite (SH), hydrogen peroxide (HP), and electrolyzed oxidizing water (EOW)

Treatment	Time(min)	Color	Texture	Smell
Tap water	1	4.64±0.02^{a1}	4.63±0.02^{a1}	2.60±0.02^{a1}
	3	4.69±0.02^{a1}	4.60±0.02^{a1}	2.64±0.01^{a1}
	5	4.63±0.02^{a1}	4.61±0.02^{a1}	2.62±0.02^{a1}
SH				
25 ppm	1	4.66±0.02^{a1}	4.66±0.08^{a1}	2.61±0.02^{a1}
	3	4.69±0.02^{a1}	4.68±0.02^{a1}	2.63±0.02^{a1}
	5	4.60±0.02^{a1}	4.63±0.02^{a1}	2.67±0.02^{a1}
50 ppm	1	4.64±0.02^{a1}	4.59±0.02^{a1}	2.64±0.02^{a1}
	3	4.63±0.02^{a1}	4.56±0.02^{a1}	2.68±0.14^{a1}
	5	4.71±0.08^{a1}	4.60±0.07^{a1}	2.71±0.11^{a1}
75 ppm	1	4.61±0.09^{a1}	4.64±0.05^{a1}	2.66±0.08^{a1}
	3	4.60±0.02^{a1}	4.66±0.05^{a1}	2.72±0.02^{a1}
	5	4.61±0.05^{a1}	4.72±0.16^{a1}	2.64±0.07^{a1}
EOW				
25 ppm	1	4.61±0.07^{a1}	4.59±0.09^{a1}	2.65±0.07^{a1}
	3	4.63±0.04^{a1}	4.65±0.05^{a1}	2.66±0.08^{a1}
	5	4.63±0.07^{a1}	4.64±0.05^{a1}	2.63±0.04^{a1}
50 ppm	1	4.56±0.08^{a1}	4.69±0.09^{a1}	2.67±0.02^{a1}
	3	4.59±0.14^{a1}	4.60±0.07^{a1}	2.60±0.04^{a1}
	5	4.73±0.05^{a1}	4.61±0.12^{a1}	2.61±0.02^{a1}
75 ppm	1	4.61±0.05^{a1}	4.64±0.07^{a1}	2.64±0.04^{a1}
	3	4.68±0.11^{a1}	4.64±0.05^{a1}	2.63±0.04^{a1}
	5	4.61±0.09^{a1}	4.71±0.12^{a1}	2.60±0.07^{a1}
HP				
25 ppm	1	4.64±0.08^{a1}	4.63±0.05^{a1}	2.60±0.04^{a1}
	3	4.71±0.07^{a1}	4.60±0.11^{a1}	2.63±0.09^{a1}
	5	4.67±0.07^{a1}	4.61±0.08^{a1}	2.66±0.02^{a1}
50 ppm	1	4.64±0.05^{a1}	4.72±0.05^{a1}	2.60±0.07^{a1}
	3	4.61±0.11^{a1}	4.64±0.04^{a1}	2.67±0.05^{a1}
	5	4.58±0.08^{a1}	4.61±0.01^{a1}	2.61±0.04^{a1}
75 ppm	1	4.62±0.02^{a1}	4.61±0.07^{a1}	2.65±0.04^{a1}
	3	4.75±0.11^{a1}	4.64±0.02^{a1}	2.59±0.08^{a1}
	5	4.64±0.07^{a1}	4.74±0.12^{a1}	2.65±0.07^{a1}

In other studies, Barut Gök and Pazır (2019) determined that there is no difference in appearance, texture, taste, and color compared to tap water of olives treated with EOW and chlorinated water at different concentrations. As a result of another study, red sweet pepper and cress, which were treated for 2 min with 1% and 5% H_2O_2, were found to have no difference in terms of aroma, texture, color, and general taste (Alexandre et al., 2012).

Conclusions

The effects of several dipping solutions on the *Eruca vesicaria* in terms of color, texture, and sensory were investigated in this study. As a result of these examinations, there was no statistical difference in terms of time in the treatment with tap water. At the same time, there was no difference in terms of both time and concentration in the treatments with chlorine, EOW, and H_2O_2. Furthermore, these results are consistent with sensory analyses. In this study, it was determined that three washing solutions did not have a negative effect on the quality of green leafy vegetables. However, in studies with such solutions, their microbiological effects were investigated. There are few studies examining the effects of quality on fruits and vegetables. Therefore, we would like to emphasize the importance of this study. Thus, it is recommended that more studies of this kind be carried out.

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