RESEARCH ARTICLE

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Arginine: a useful treatment to delay enzymatic browning of fresh-cut pear and apple

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Abstract

This study examined the effect of arginine treatments on the prevention of enzymatic browning in fresh-cut apples and pears. For this, 0, 25, 50, 75, and 100 mM, and 0-, 50-, 100-, and 200-mM arginine solutions were prepared for apples and pears, respectively. Slices of both fruits were dipped in these solutions for 5 min and dried for 20 min. Then, they were packaged and stored at 5±1°C temperature and 80-90% relative humidity for 18 days for pears and 12 days for apples. Browning index, color values, weight losses, firmness of slices, and total soluble solids were examined at three-day intervals during storage. The results showed that arginine treatment retarded the enzymatic browning of both apple and pear slices. While arginine suppressed browning at increasing doses, especially at 200 mM in pears, it retarded browning in apple slices at all concentrations. In addition, the fact that the L values were higher than the control and water control applications showed that both apple and pear slices remained lighter in color. Hue values supported both the L and browning index results. Arginine treatment decreased the weight loss; however, it did not affect the firmness of the slices. In addition, arginine treatments did not have a significant effect on the total soluble solid content of apple and pear slices.

Keywords: Arginine, Browning, Fresh cut, Apple, Pear, Color

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INTRODUCTION

Fresh-cut products are fruit and vegetables whose shape physically changed, washed, peeled, cut, sliced, chopped, etc, and are 100% usable. The quality components of fresh-cut products are color, appearance, taste, flavor, texture, and nutritional value. Metabolic changes occurring in fresh-cut products and affecting the quality are the increase in ethylene production and respiration rate, discoloration, enzymatic browning, and microbial contamination. Although the nutritional quality and freshness of these fresh-cut products are high, the quality, especially color quality, is quickly reduced due to the removal of the protective layer during minimal processing. (Erbay and Demir, 2006; Kasım and Kasım, 2016). Browning of the cut surface is a crucial factor in reducing the quality of fresh-cut fruit and vegetables. The polyphenol oxidase, peroxidase, and other enzymes released from the cut cell unite in fruits and vegetables containing phenolic compounds with the oxygen molecule in the air, forming brown pigments called melanin. This reaction is called enzymatic browning, and different treatments can delay this. One of these applications is arginine treatment.

Arginine is an amino acid, which was found in previous studies that post-harvest arginine treatments improved tolerance to diseases, delayed enzymatic browning, reduced ethylene production, and therefore, lengthened storage life and maintain the quality of fruit and vegetables (Wang et al., 2017; Babalar et al., 2018; Hasan et al., 2019; Shu et al., 2020). Arginine has recently studied for its inhibiting effect on enzymatic browning in fresh-cut fruits and vegetables. In a study, it was found that 50 ppm arginine treatment effectively delayed enzymatic browning symptoms in fresh-cut red cabbage compared with the control and 100 ppm (Nilprapruck, 2020). Also, in another study 50 mM arginine showed a similar effect in fresh-cut apples, whereas 100 mM was more successful in fresh-cut lettuce slices (Wills and Li, 2016). Furthermore, Prabasari et al. (2020), showed that L arginine treatments inhibited the synthesis of phenolics that caused browning in fresh-cut salacca.

However, there are almost no studies on the effect of arginine on the inhibition of browning in fresh-cut apples and pears. Therefore, this research aimed to investigate the effect of different doses of arginine on reducing browning in fresh-cut apple and pear slices.

MATERIALS AND METHODS

Plant material

The 'Starking' apple and 'Deveci' pear fruits, used in the experiment were bought from the Kocaeli Wholesaler Marketplace. The fruits are in the extra quality class with 60-65 mm diameter for apples and 60 mm for pears. The fruits were immediately transferred to the Postharvest Laboratory of the Agricultural Faculty, Horticulture Department.

Preparation of fruits for dipping treatments

The fruits were washed first for both surface disinfection and cooling. The washed fruits were cut with a sharp knife into eight slices without peeling the skin.

Arginine treatment and drying

Arginine solutions were prepared at 0, 25, 50, 75, and 100 mM, and 0, 50, 100, and 200 mM for apples and pears, respectively. Seventy-two pear or apple slices from each treatment group were dipped into a 3-liter solution for 5 min separately. Two controls were used in the study. In the dry control (C), slices of fruits did not dip into any solution, and in the second control (CW), fruit slices were dipped only in tap water. The arginine-treated fruit slices were left to dry on filter paper for 20 min to prevent decay during storage.

Packaging and storage conditions

Four slices of apples and pears in each treatment were packaged separately into a plastic box with a lid, 50 mm in height, 115 mm in width, and 125 mm in length. These packaged fruits were held in cold storage at 5±1°C temperature and 80-90% relative humidity for 18 days for pears and 12 days for apples.

Color measurements

The color measurement of fruit slices was conducted using a Minolta CR-400 chroma meter with a D65 lamp, on three points of each fruit slice in each replicate. The device was calibrated using a standard white calibration plate. Color values were measured as L*, a*, and b*. The color L* value in the chroma meter shows the brightness or whiteness of the fruit slices. In addition, the browning index (BI) and hue values were calculated from a* and b* values using the following formulas:

$$BI = [100\ (X-0.31)]/0.17, \text{ where } x=(a^*+1.75L^*)/(5.645L^*+a^*-0.3012b^*)$$

$$h^o = tan^{-1}\left(\frac{b^*}{a^*}\right) when\ a^* > 0\ and\ b^* > 0, or\ h^o = 180 + tan^{-1}\left(\frac{b^*}{a^*}\right) when\ a^* < 0\ and\ b^* > 0$$

Weight loss (%)

The three packages from each treatment group and each fruit were labeled and weighed each analysis period for determining weight loss of fresh-cut fruit slices. Next the weight loss was calculates as:

Weight loss (%) = ((Initial weight-the weight at each analysis period) x100)/ Initial weight.

Total soluble solids (TSS, %)

TSS from fruit juice was detected using an Atago DR-A1 digital refractometer (Atago Co. Ltd. Japan). Fruit juice from four fruit slices from each replicate was used for measurements. The TSS measurement was conducted in three replicate.

Fruit firmness (N)

Fruit firmness was measured from three fresh-cut fruit slices in each replicate using a Shimadzu EZ-LX texture analyzer.

Statistical analysis

The experiments were conducted using a completely randomized experimental design. The study was conducted with three replicates and five fruit slices in each replicate for both apple and pear. The data were processed using SPSS 16 software. The differences in treatments were compared using Duncan's multiple range tests, at $p<0.05$ error limit.

RESULTS AND DISCUSSION

Browning index

The browning index (BI) of pear slices was 9.79 at the beginning of the study and increased from the third day and ranged from 12.49 to 18.84 (Fig.1). However, all arginine treatments suppressed the increase in BI until the 12th day, and 200 mM arginine treatment continued this effect during 18 days of storage (Fig.2).

A similar situation was observed in apple slices, and all arginine treatments prevented an increase in BI during storage, particularly at increasing doses (Fig.3). Previous studies have found that arginine treatments delayed or inhibited enzymatic browning in fresh-cut fruit and vegetables (Wang et al., 2017; Shu et al., 2020). In

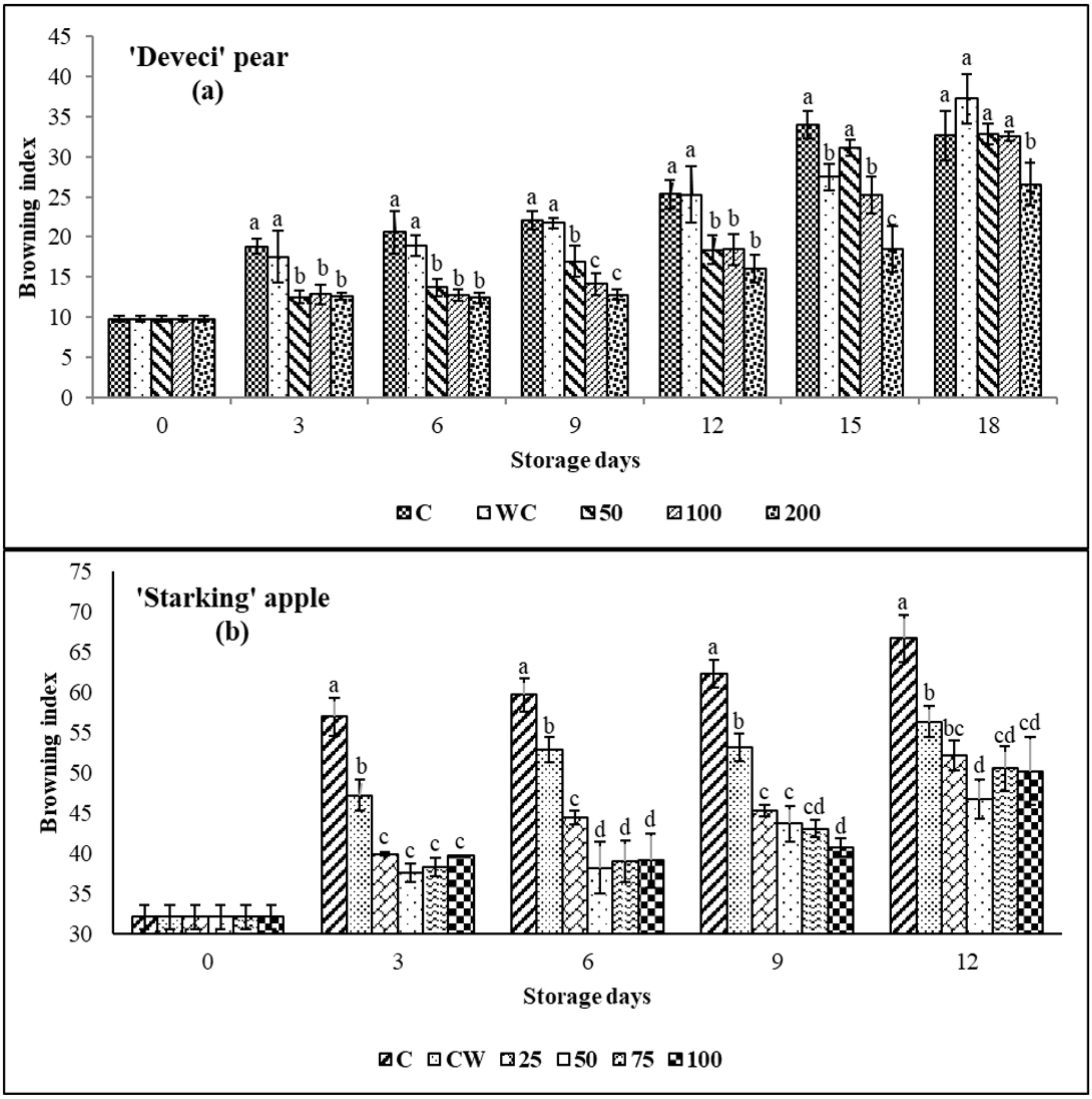

Figure 1. Browning values of fresh-cut pear (a) and apple (b) slices during storage. The letters above the bar represent differences among the treatments at $p<0.05$.

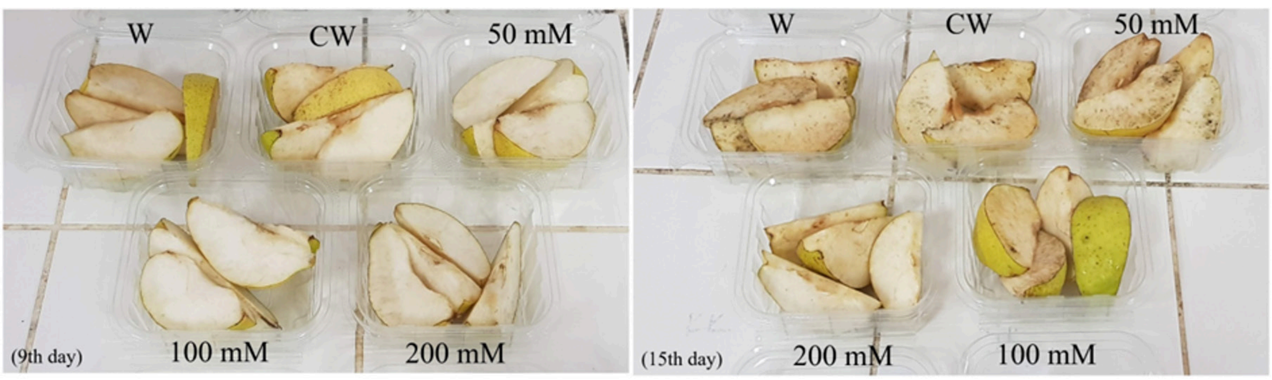

Figure 2. Appearance of pear slices after the ninth and fifteenth days of storage.

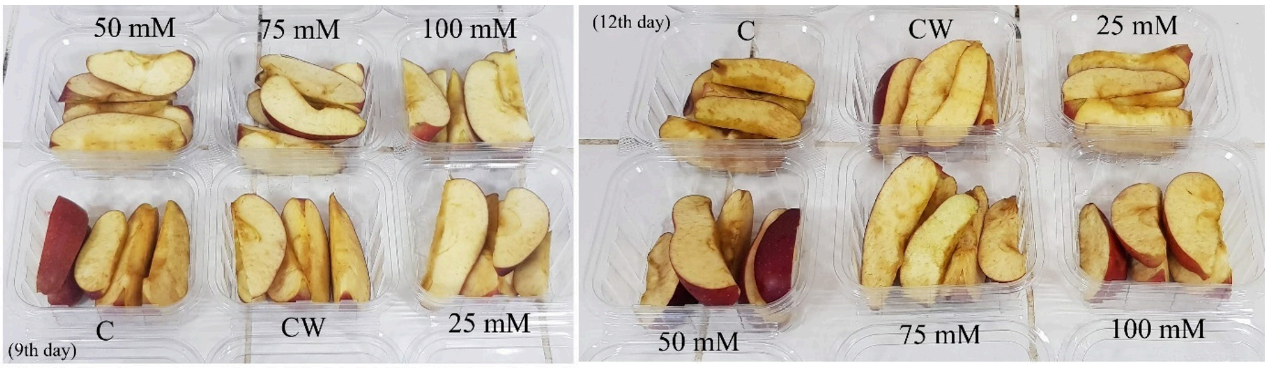

Figure 3. Fresh-cut apple slices after the ninth and twelfth days of storage

addition, Nilprapruck (2020) stated that 50 mM arginine treatment retarded enzymatic browning, and Wills and Li (2016) 50 ppm for fresh-cut apples and 100 ppm for fresh-cut lettuce successfully delayed enzymatic browning. All arginine treatments delayed an increase in BI, an indicator of enzymatic browning, particularly the highest dose as in previous studies. Furthermore, the L values of arginine-treated pear slices were higher than those of C and CW, and this has shown that the result arginine prevents an increase in browning.

L values

L values of fresh-cut pear and apple fruit were higher at all arginine treatments for 12 days in pears and nine days in apples compared with C and CW treatments. The L values of pear slices treated with 100- and 200-mM arginine remain high during the 18 days of storage (Fig 4). The results showed that the arginine treatments were quite efficient on L values or whiteness of fruit slices (Fig. 5). L values of fresh-cut fruit slices decreased on the third day in all treatments compared with initial levels. However, the L values of arginine-treated slices were higher than those of C and CW during storage. High L levels indicate that the color of slices is more bright or white, while low ones mean indicate darker or black. Besides, the browning index values of slices confirm these findings because the BI values of arginine-treated slices are lower than those of C and CW.

Hue values

The hue angle values of fresh-cut pear slices decreased from 94.29 to 89.05 and 89.23 in the C and CW treatments on day three, whereas it was close to or higher than the initial values in arginine treatments, and it changed to 94.16, 94.3, and 94.70 in 50 mM, 100 mM, and 200 mM arginine treatments, respectively. Moreover, the hue values of arginine-treated pear slices remained high compared with C and CW throughout storage. In other words, arginine applications ensured that the color of the pear slices was preserved without changing much compared with the initial color during storage (Fig. 6).

Weight losses

In the study, the lowest weight loss of pear slices was observed with CW and 50 mM arginine treatment, and the differences between these treatments and C were significant ($p<0.05$). The other arginine treatments, however, did not show a decreasing effect on weight loss (Table 1). Arginine treatments, except for 50 mM, slowed the weight loss increase in fresh-cut apples, but the differences among treatments were not found to be significant (Table 1). The fresh-cut process, i.e., the cutting of fruits or vegetables removes the protective layer above the cells; tissue becomes vulnerable to environmental conditions. This phenomenon leads to increased weight loss, due to increased respiration and transpiration during storage. Increased weight loss causes decreased freshness and loss of visual quality. Weight losses of pear slices increased with increasing storage duration, whereas these losses were low and ranged from 0.034% to 0.308% during storage. In addition, the weight loss increased during storage as expected, up to 0.318% at the end of storage, but this loss did not affect the appearance of the fresh-cut apples. Wang et al. (2023) stated that the weight loss of blueberry fruits increased during the 10-day storage period in control and arginine treatments. In the present study, in line with researchers, the weight loss of fruit slices of pear and apple in all treatment groups was increased during storage. In addition, the authors expressed the fruit WL was significantly lower in the 1-mM arginine-treated group than in the control group. Similarly, in the study, the weight loss of all arginine-treated pear slices was lower than in the control; the same trend was observed in apple slices except for the 50 mM treatment, in which the weight loss was the highest. Wang et al. (2017) reached the same findings in green asparagus spears to which they applied arginine.

Firmness of the slices

The firmness of the slices is an important quality criterion for consumer choices. The firmness of both pear and apple (Table 2) slices fluctuated during storage. The firmness of pear slices was the highest in C and apple slices at 50 mM. However, the arginine treatments did not cause significant differences in fruit firmness in pear or apple slices. Actually, arginine is a polyamine that is strongly bonded to pectin in the middle lamella

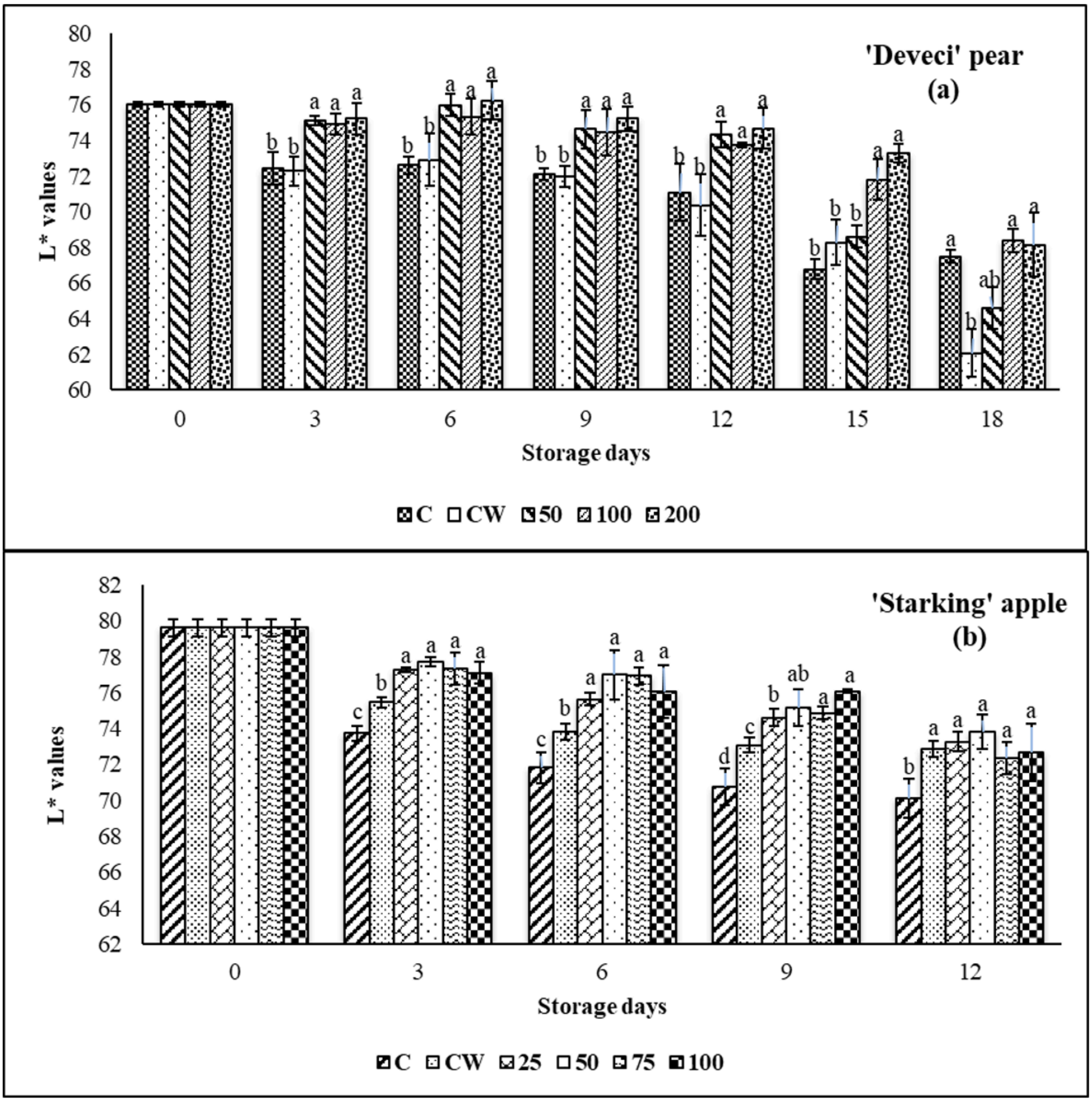

Figure 4. L values of fresh-cut pear (a) and apple (b) slices during storage. The letters above the bar represent differences among the treatments at p<0.05.

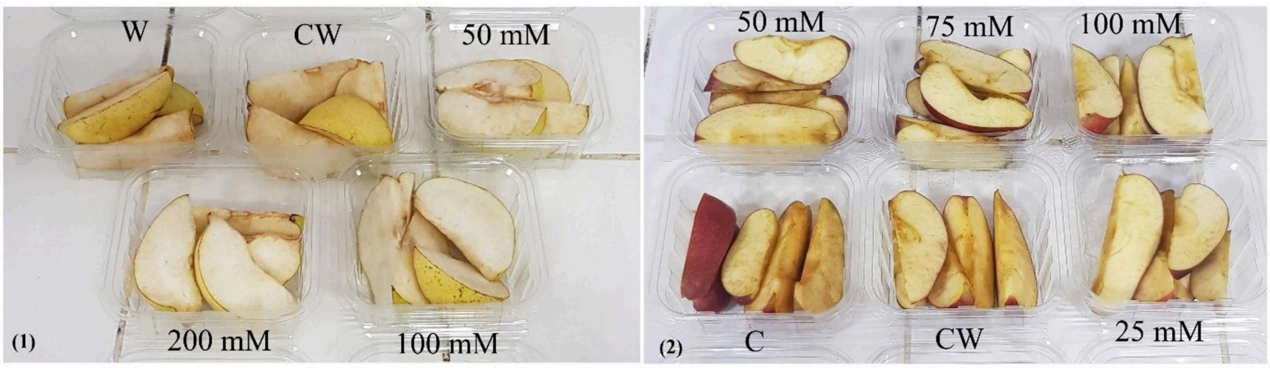

Figure 5. The appearance of fresh-cut and arginine-treated pear and apple slices. Pear slices on day 12 (1), and apple slices on day 9 of storage (2). C: Control, CW: Water control.

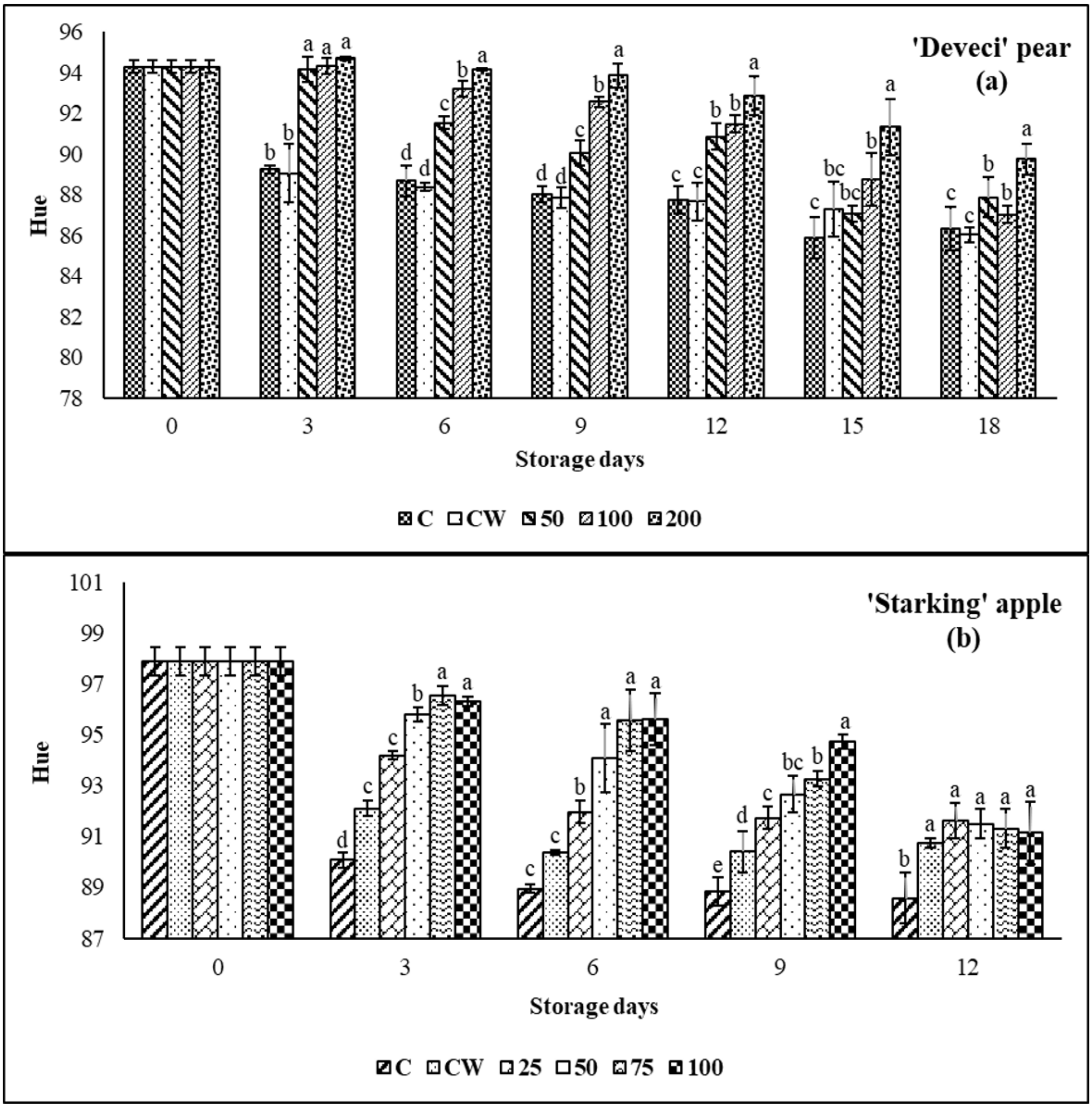

Figure 6. Hue values of fresh-cut pear (a) and apple (b) slices during storage. The letters above the bar represent differences among the treatments at $p<0.05$.

and increases the strength of the cell wall (Valero et al., 1998; Shan et al., 2007). Therefore, it is expected that the arginine treatments increased the firmness of fresh-cut pears and apples. The arginine treatment, however, did not increase the firmness of the slices. Wang et al. (2023) declared that the fruit firmness of both in 1 mM arginine-treated blueberry fruit and control groups decreased and remained at a lower level than the initial value during the whole storage period. On the other hand, Li et al. (2019) stated that treatment with a 10-mM L-arginine maintained the tissue firmness of mushrooms. In the present study, however, the fruit firmness of both arginine treatment and C and CW in pear and apple slices were higher compared with the initial value and at the end of the storage. In addition, the authors found that the fruit firmness of arginine-treated blueberry fruit was higher than in control. However, in this study, the arginine treatments were unsuccessful in maintaining firmness compared with C and CW.

Total soluble solids

The total soluble solids of pear slices were 14.6% initially but decreased in all treatments, however, it was lowest in 50 mM arginine treatment compared with the control, but the differences among the arginine treatments were insignificant (Table 3). Total soluble solids of apple slices increased in the C and 50 mM treatments, while decreased in the other treatments, 12th days of storage,

Table 1. Weight losses of 'Deveci' pear and 'Starking' apple during storage

Treatments	Weight loss (%), pears							Treatment avg.
	Days							
	0	3	6	9	12	15	18	
C	0	0.04±0.009	0.11±0.019	1.17±0.027	0.22±0.036	0.28±0.044	0.33±0.044	***0.164 a***
CW	0	0.03±0.002	0.10±0.004	0.15±0.008	0.20±0.008	0.25±0.009	0.29±0.009	***0.145 b***
50	0	0.03±0.008	0.09±0.010	0.14±0.013	0.19±0.023	0.26±0.032	0.30±0.032	***0.145 b***
100	0	0.04±0.010	0.10±0.003	0.15±0.004	0.21±0.004	0.27±0.002	0.31±0.002	***0.154 ab***
200	0	0.03±0.005	0.11±0.001	0.16±0.003	0.21±0.008	0.26±0.003	0.31±0.003	***0.154 ab***
Time avg.	***0 g****	***0.034.f***	***0.101 e***	***0.153 d***	***0.206 c***	***0.264 s***	***0.308 a***	

	Weight loss (%), apples					
	Days					
	0	3	6	9	12	
C	0	0.09±0.008	0.14±0.011	0.21±0.013	0.32±0.022	***0.152 ab***
CW	0	0.07±0.003	0.13±0.003	0.19±0.007	0.29±0.014	***0.136 b***
25	0	0.07±0.008	0.12±0.007	0.18±0.017	0.28±0.020	***0.128 b***
50	0	0.07±0.004	0.17±0.054	0.28±0.143	0.45±0.252	***0.193 a***
75	0	0.07±0.017	0.13±0.019	0.19±0.027	0.29±0.040	***0.134 b***
100	0	0.07±0.025	0.12±0.026	0.18±0.031	0.28±0.036	***0.132 b***
Time avg.	***0 e****	***0.074 d***	***0.133 c***	***0.204 b***	***0.318 a***	

*The interaction of treatment x time was insignificant at p<0,05 level.

Table 2. Fruit firmness of 'Deveci' pear and 'Starking' apple during storage

Treatments	Firmness of slices (N), pears							Treatment avg.
	Days							
	0	3	6	9	12	15	18	
C	69.57±9.15	79.49±5.88	77.32±1.12	75.50±5.41	78.28±8.89	75.00±8.24	80.71±3.76	***76.5****
CW	69.57±9.15	72.18±9.71	71.23±5.76	74.25±2.42	73.78±5.99	74.37±3.52	75.1±2.54	***72.93***
50	69.57±9.15	76.27±8.36	72.78±4.28	73.12±5.10	77.30±8.50	74.56±3.05	81.62±6.03	***75.03***
100	69.57±9.15	80.46±7.60	72.93±4.41	77.92±13.66	83.76±4.87	76.20±5.63	68.45±7.13	***75.61***
200	69.57±9.15	75.7±5.90	77.07±3.61	77.98±7.35	75.23±2.30	70.73±12.72	78.3±5.87	***74.9***
Time avg.	***69.57 b***	***76.82 a***	***74.27 ab***	***75.75 a***	***77.67 a***	***74.17 ab***	***76.84 a***	

	Firmness of slices (N), apples					
	Days					
	0	3	6	9	12	
C	31.25±1.55	38.00±2.85	41.92±4.15	34.39±6.32	36.12±3.37	***36.34****
CW	31.25±1.55	34.58±3.94	32.60±1.43	33.60±6.54	37.65±6.56	***33.94***
25	31.25±1.55	39.12±6.18	37.24±1.61	38.18±2.73	35.71±5.64	***36.30***
50	31.25±1.55	36.53±11.13	39.40±4.46	31.24±3.45	34.40±2.13	***34.56***
75	31.25±1.55	34.44±2.31	33.86±2.78	31.81±1.43	32.28±4.12	***32.73***
100	31.25±1.55	32.80±8.42	33.59±8.68	39.09±10.16	27.80±2,05	***32.90***
Time avg.	***31.25 a***	***35.91 b***	***36.43 a***	***34.72 a***	***33.99 ab***	

*The interaction of treatment x time was insignificant at p<0,05 level.

**Differences between treatments was non-significant.

compared with the initial. While the 50 mM treatment was prominent from this point, differences between this treatment and C and 25 mM were insignificant. In addition, it was observed that the CW and 75- and 100-mM arginine treatments have a reducing effect on total soluble solids compared with 50 mM. In the present study, the TSS of both pear and apple slices was lower than C at the first three days, but at six days, the TSS of apple slices treated with 50 mM arginine, and pear slices treated with 100 and 200 mM was higher compared with the other treatments. After that, 25- and 50 ppm arginine treatment increased the TSS of apple slices and the TSS of 100- and 200 ppm arginine-treated pear slices were higher than 50 ppm but lower in C and CW. Shu et al. (2020) showed that the TSS of arginine-treated strawberry fruits increased and then decreased. Besides, they found that the TSS of 1 mM arginine-treated fruits was significantly higher than that of control, 0.5 and 5 mM. In this study, the arginine doses used were higher than those used by Shu et al. (2020), and the TSS contents of 200 mM arginine-treated slices in pear and 50 mM in apple remained high.

Table 3. Total soluble solids of 'Deveci' pear and 'Starking' apple during storage

Treatments	Total soluble solids (%), pears							Treatment avg.
	Days							
	0	3	6	9	12	15	18	
C	14.60±0.40	14.53±0.67	14.20±0.62	14.57±1.10	14.80±0.89	14.67±1.01	14.53±1.29	***14.56 a****
CW	14.60±0.40	14.13±0.68	14.17±1.00	14.33±0.78	14.70±0.85	14.00±0.26	14.43±0.12	***14.34 ab***
50	14.60±0.40	14.17±0.49	13.97±0.60	13.73±1.08	13.53±0.47	13.13±0.64	13.93±0.57	***13.87 b***
100	14.60±0.40	14.13±0.49	14.87±0.80	14.37±0.40	14.40±0.72	13.33±1.00	14.03±0.38	***14.25 ab***
200	14.60±0.40	13.83±0.55	14.70±0.61	14.70±0.46	14.50±0.98	14.03±1.43	14.13±1.00	***14.36 ab***
Time avg.	14.60 a	***14.16 ab***	***14.38 ab***	***14.34 ab***	***14.39 ab***	***13.83 b***	***14.21 ab***	
	Total soluble solids (%), apples							
	Days							
	0	3	6	9	12			
C	13.40±0.35	13.80±0.26 **a****	12.80±0.60 **b**	13.47±0.75 **a**	13.60±0.85 **ab**			***13.41***
CW	13.40±0.35	12.60±0.66 **bc**	12.80±0.44 **b**	13.03±0.23 **ab**	12.43±0.15 **c**			***12.85***
25	13.40±0.35	13.60±0.61 **ab**	12.60±0.10 **b**	13.87±0.40 **a**	13.30±0.53 **abc**			***13.35***
50	13.40±0.35	13.60±0.36 **ab**	13.70±0.26 **a**	13.70±0.46 **a**	13.87±0.06 **a**			***13.65***
75	13.40±0.35	12.47±0.71 **c**	12.77±0.21 **b**	12.97±0.55 **ab**	12.63±0.21 **bc**			***12.85***
100	13.40±0.35	13.50±0.60 **abc**	12.90±0.50 **b**	12.37±0.47 **c**	12.63±0.75 **bc**			***12.96***
Time avg.	***13.4***	***13.26***	***12.93***	***13.23***	***13.08***			

*The interaction of treatment x time was insignificant at p<0,05 level. **The interaction of treatment x time was significant at p<0,05 level.

CONCLUSIONS

The effect of arginine treatment on the browning index and other quality parameters of fresh-cut pears and apples during storage were studied. The 200 mM arginine treatment was the most effective in retarding browning in pear slices, whereas all arginine concentrations delayed browning in apples. Therefore, we suggest that arginine treatments can delay/prevent enzymatic browning of fresh-cut pears and apples. Also, we found that the arginine treatments had a positive effect on weight loss but did not affect fruit firmness and total soluble solids.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of interest

The authors declared that for this research article, they have no actual, potential or perceived conflict of interest.

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the Text, Figures, and Tables are original and that they have not been published before.

Ethical approval

Ethics committee approval is not required.

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Data availability

Not applicable

Consent for publication

Not applicable

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