EFFECT OF PRETREATMENTS ON COLOR OF DEHYDRATED DIFFERENT APPLE CULTIVARS DURING STORAGE

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Abstract
Apple slices obtained from Amasya, Golden delicious and Starkrimson delicious cultivars were dipped into ascorbic acid (AA), erythorbic acid (EA) and sulphur dioxide solutions before dehydration and then changes in color values, browning index and ascorbic acid contents of the dehydrated apple chips were studied during storage. The effects of applied solution and storage time on L, a and b values of dehydrated apple chips were found important during storage. The L value of dehydrated apple samples was significantly higher than that deep into sulphurdioxide (SO_{2}) solution. Increasing concentration of AA and EA solutions 1% to 1.5% were not effective preservation of sample color. Similar effects were reported at SO_2 solution a value of the samples rapidly increased within the last four month of storage. The lowest a values were dipped into SO_2 solutions. The highest browning values of the samples were observed deep into ascorbic acid solutions. Loss of ascorbic acid content was found 59.5% at end of 4.th month and 92.7% at end of 8.th month. Sodium sulphite was the most effective in preventing browning. Ascorbic acid and erythorbic acid (1%-1.5%) was not very effective as browning occurred during storage. Golden delicious were determined suitable cultivar for dehydration.

Keywords: Apple, Color, Dehydrated apple, ascorbic acid, erythorbic acid, sulphite, Browning Index

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1. INTRODUCTION

Color changes have been found to be one of the major problems in preserving cut fruits. Apples are an example of fruits that are susceptible to enzymatic browning. The browning reactions in apples appear to be a complex process involving several factors. Nature and levels of substrates, the enzymatic activity and the presence of inhibitors or promoters influence the browning the major factors involved. The extent that each will contribute to the browning reaction is dependent on the cultivar (Coseteng and Lee, 1987; Rocha *et al.*, 1998).

Plant tissues as such as apple exhibited extensive browning during their drying and subsequent storage. Fruits that are cut and dried require some type of treatment if they are retain their light color (Bolin and Stele, 1987).

Browning of cut fruits owning to presence of polyphenols is one of the major problems in apple drying. It was shown earlier that the darkening of fruit tissues in air is due to an enzymatic oxidation of phenolic substance present in the tissue (Bhardwaj and Kaushall, 1990).

The main treatments consist of initial addition of sulphite to the product before drying. This not only inhibits enzymatic browning from occurring during the drying operation, but also provides some protection from the occurrence of nonenzymatic browning during storage. Sulphur dioxide has long been considered a safe product for incorporation into foods and food products. At its current usage rate, it is not been harmful to the majority of the population (Taylor *et al.*, 1986). Recently however, the extreme sensitivity of a few people to sulphite has come to public attention. Because of this, more information is needed on alternative methods of controlling the development of darkening in food products. Sapers and Ziolkowski (1987) added erythorbic or ascorbic acid to eliminate the enzymatic browning of cut surfaces of apples in order to eliminate the use of sulphur dioxide from treatment prior to drying. Alternate commercially applicable methods already exist for retarding enzymatic browning, such as with an ascorbic acid/citric acid dip; however no such method is available for nonenzymatic browning.

Ascorbic acid is most often used antioxidant as it is easily oxidized by enzymes and oxygen during processing and storage.

Disadvantageously degradation products of ascorbic acid are dark. The search for enzymatic browning inhibitors still continues. Among them ascorbic acid-2-phosphate, ascorbyl palmitate, erythorbic, cinnamic, citric, benzoic acids, phosphate, sodium or calcium chloride, cyclodexrtin, carregen and many other proposed (Oszmianski *et al.*, 1995).
Alternative treatments to control enzymatic browning, mostly formulations of ascorbic acid (AA), erythorbic acid (EA) or their sodium salts with citric acid, have been developed (Langdon, 1987). Santerre *et al.* (1988) suggested that 0.5% D-araboascorbic acid might be substituted for 1% L-ascorbic acid to treat 'Spy' and 'Jonathan' apple spices prior to freezing, because it maintained color and sensory properties as well, and is less expensive than L-ascorbic acid. However, these alternatives are considered to be less effective than sulphite because of insufficient penetration into the cellular matrix (Taylor *et al.*, 1986). Furthermore, AA is easily oxidized by endogenous enzymes or by iron or copper catalyzed autoxidation. When oxidized by these reactions or in the course of its intended role as browning inhibitor, AA may fall into a concentration range where it exerts prooxidant effects. EA appears to be more easily oxidized than AA (Borenstein, 1965; Sapers and Ziolkowski 1987; Sapers *et al.*, 1989).
The aim of this research was to determine the effects of dipping solutions (ascorbic acid (AA), erythorbic acid (EA) and sulphurdioxide (SO_2)) during storage on the color, degree of browning and ascorbic acid content of dehydrated apple slices obtained from Amasya, Golden delicious and Starkrimson delicious cultivars.

2. MATERIALS AND METHODS

Amasya, Golden delicious and Starkrimson delicious cultivars were obtained directly from the experimental orchard of the Horticultural Department of Çukurova University. The fruits were held in a cold storage room (+5°C) until processing.
The fruits after washing and coring were made into rings of about 1.6 mm thicknesses with a hand-operated slicer (Krups, Solingen, Germany). Sliced apples were immersed in different 1000 and 2000ppm SO_2, 1%citric acid (CA), 1-1.5%L-ascorbic acid (AA), 1-1.5% erythorbic acid (EA) solution and 1%CA+1%AA, 1%CA+1%EA, 1%CA+1.5%AA, 1%CA+1.5%EA solutions and water (as a control) for about 2 min before dehydration. Apple slices directly after immersing were placed on perforated trays of a cabinet dehydrator (custom-made). Samples were dehydrated at 75±2°C with hot air current. Dehydration was carried out until the dry matter content reached to 96% (about 5 h). The experiments were made in 3 replicates. The chips were packed in polyethylene packages (about 25 g).
Color parameters (L, a, b), browning index and ascorbic acid were applied on samples taken at 4 month intervals during storage period (for 8 months) at room temperature. All analyses were carried out in duplicates.

2.1 Dry matter content

Dry matter content was measured by drying samples under vacuum at 70 ◦C to a constant weight (AOAC, 1990).

2.2 Determination of color

Cut surface was measured with a tristimulus reflectance colorimeter (Hunter Lab colorimeter Model D25C-3). Color was recorded using a CIE-L,a,b uniform color surface (-Lab), where L indicates lightness, a indicates chromaticity on a green (-) to red (+) axis, and b indicates chromaticity on a blue (-) to yellow (+) axis (Linskens and Jackson, 1995). The instrument was calibrated using the standard white reflector plate.

2.3 Determination of Browning Index

10 grams of samples were added into beakers containing 250mL distilled water. The sample was homogenized in the blender at max speed for 1 min. The homogenate was centrifuged at 800xg for 20 min. Approximately 1 h from the time of homogenizing, 15mL of 95% ethanol was added to 10mL of the supernatant. The mixture was shaken and then centrifuged again at 800xg for 20 min. The degree of browning of the supernatant was determined by

measuring the absorbance at 440nm using the spectrophotometer (Coseteng and Lee, 1987).

2.4 Determination of Ascorbic Acid Content

Content of ascorbic acid in dehydrated apple were extracted with oxalic acid and determined with 2-6, diclorophenolindophenol at spectrophotometer (Absorbance at 518 nm). The amount of ascorbic acid (expressed as mg L-ascorbic acid/100g) was calculated from a standard curve (1–4 mg/100 mL L-Ascorbic Acid) prepared at the same time (Hişil, 1993).

2.5 Statistical analysis

The software SPSS 10.0 for Windows was used for analysis of variance of the data. The statistically significant differences of means were defined as p<0.01 and P<0.05 using Duncan's significance difference test (Copright © SPSS Inc., Chicago, Illinois, US).

3. RESULTS AND DISCUSSION

3.1 Changes in color values during storage

The color of apple is important to their acceptability. Apple tissues exhibit extensive browning during drying and subsequent storage (Krokida *et al.*, 2001).

3.1.1 Changes in L value

During storage L values of samples were given at Table 1. In this research, it was determined AA and EA were similar effectiveness on control of enzymatic browning at cut surface of apple. The highest L value and the lightest color of sample were submerged in SO_2 solution. Increasing concentration of AA and EA solution 1% to 1.5% didn't affect preservation of sample color. Similar effects were reported at SO_2 solution. Because of this it was though that enough solution of low concentration for preservation of color. Effect of pre-treatment was found significant statistically on the L values (p<0.01).

At dehydration, treatment SO_2 helps preventing of browning. Sulphur dioxide is a good color preservative of fresh fruit and vegetable, as it retards enzymatic and nonenzymatic browning reaction. Also SO_2 provide regulation of dark color (Taylor *et al.*, 1986).

The L values of apple chips were not significantly influenced by ascorbic acid and its isomer. There was a significant influence of storage time on the color of dried all cultivar apple chips (p<0.01). L values of sample were decreased during storage. This change was slower for first 4^{th} month, than $8.^{th}$ month. Differences of L values between cultivars were found statistically significant (p<0.01). The lightest color was determined Golden delicious. Santere *et al.* (1988) reported the Hunter L values of spy cultivar apple slices was not significantly influenced by ascorbic acid isomer but there was a significant influence of storage time color of apple slices.

3.1.2 Changes in a value

That redness (a) of dehydrated apple was strongly affected by storage time; redness was increased during storage period (Table 2). Differences of pre-treatment were found significant statistically on a value (p<0.01). The lowest a value were recorded deep into SO_2 solutions. Concentration of SO_2 was not significant. A significant influence of storage time and cultivar on a values of apple chips was recorded (p<0.01). Golden delicious cultivar has the lowest a value.

Krokida *et al.* (2001) reported that the a value of dried apple was increased significantly during air drying and increasing of a values denotes a more red chromo which is indicative of the browning reaction. They were determined dipping into SO_2 solution also prevents redness deterioration during convective drying. Redness was found to be significantly affected by all pretreatments. The comparison between treatment means indicated sodium sulphite was the best anti-browning agent with regard to value of L and a and browning index changes during storage.

L* value is an indicator not only for the oxidative browning reaction but also an indicator that shows the increase in the pigment concentration. However a* value gives information for the color change in the fresh apple tissue. The decrease in the L* value and increasing of a* value may be indicators of browning (Monsalve-Gonzalez *et al.*, 1993; Rocha and Morais, 2003).

Table 1. L values of dehydrated apple cultivars during storage.

Treatments	Amasya			Golden delicious			Starkrimson delicious		
	Months								
	0	4	8	0	4	8	0	4	8
Water (Control)	70.89 ^{bc}	71.77 ^{b}	69.98 ^{b}	76.32 ^{bcd}	73.92 ^{c}	72.81 ^{d}	71.79 ^{b}	70.20 ^{b}	69.33 ^{b}
1000 ppm SO_2	83.43 ^{a}	82.09 ^{a}	73.83 ^{a}	74.43 ^{c}	72.62 ^{c}	72.17 ^{e}	63.68 ^{def}	62.38 ^{cd}	58.26 ^{ef}
2000 ppm SO2	81.76 ^{a}	81.19 ^{a}	74.62 ^{a}	75.83 ^{cd}	75.12 ^{bc}	74.66 ^{cd}	66.58 ^{cd}	63.17 ^{cd}	58.22 ^{ef}
1 % C.A.	62.29 ^{fg}	59.84 ^{d}	58.05 ^{ef}	81.83 ^{a}	81.54 ^{a}	77.80 ^{a}	80.59 ^{a}	78.31 ^{a}	76.92 ^{a}
1 %A.A.	71.39 ^{bc}	68.88 ^{bc}	65.31 ^{c}	81.14 ^{a}	81.22 ^{a}	77.83 ^{a}	78.86 ^{a}	79.00 ^{a}	75.52 ^{a}
1 % E.A.	73.43 ^{b}	71.87 ^{b}	67.25 ^{bc}	79.50 ^{ab}	78.69 ^{ab}	71.95 ^{e}	60.09 ^{g}	59.46 ^{cd}	58.82 ^{de}
1.5 % A.A.	67.04 ^{de}	64.89 ^{c}	61.28 ^{de}	72.32 ^{c}	72.62 ^{c}	72.17 ^{e}	66.50 ^{cd}	64.18 ^{c}	63.15 ^{c}
1.5 % E.A.	69.02 ^{cd}	69.72 ^{bc}	66.92 ^{bc}	78.93 ^{abc}	76.62 ^{bc}	72.62 ^{de}	67.40 ^{c}	60.95 ^{cd}	55.92 ^{ef}
1%C.A.+ 1% A.A.	63.90 ^{efg}	60.09 ^{d}	52.71 ^{g}	77.33 ^{bcd}	75.66 ^{bc}	72.32 ^{de}	65.76 ^{cde}	65.10 ^{c}	61.56 ^{cd}
1%C. A.+ 1% E.A.	65.67 ^{def}	62.37 ^{d}	59.28 ^{e}	78.56 ^{abc}	76.33 ^{bc}	71.80 ^{e}	61.56 ^{fg}	61.15 ^{d}	57.51 ^{ef}
1%C.A.+1.5%A.A.	61.57 ^{g}	61.34 ^{d}	55.38 ^{fg}	77.12 ^{bcd}	76.43 ^{bc}	75.58 ^{b}	68.54 ^{bc}	64.80 ^{c}	62.52 ^{c}
1%C.A.+1.5%E.A.	73.47 ^{b}	67.80 ^{bc}	64.46 ^{cd}	77.52 ^{bcd}	75.03 ^{bc}	74.54 ^{cd}	62.68 ^{efg}	61.38 ^{cd}	55.10 ^{f}

*Significant differences between means ($p<0.01$) are expressed by different letters. The letters compare values in the same column.

Table 2. a values of dehydrated apple cultivars during storage.

Treatments	Amasya			Golden delicious			Starkrimson delicious		
	Months								
	0	4	8	0	4	8	0	4	8
Water (Control)	2.24 ^{c}	1.80 ^{cd}	4.14 ^{e}	-0.87 ^{bc}	-0.62 ^{bc}	2.21 ^{bc}	1.93 ^{d}	2.30 ^{d}	4.45 ^{ab}
1000 ppm SO_2	-4.30 ^{e}	-3.30 ^{e}	1.18 ^{f}	-3.67 ^{de}	-4.09 ^{ef}	-0.84 ^{d}	-4.95 ^{e}	-3.35 ^{e}	0.38 ^{e}
2000 ppm SO2	-4.38 ^{e}	-3.41 ^{e}	-0.02 ^{f}	-4.00 ^{e}	-4.44 ^{f}	-0.87 ^{d}	-4.95 ^{e}	-4.34 ^{e}	0.87 ^{de}
1 % C.A.	8.84 ^{a}	9.84 ^{a}	11.14 ^{a}	4.03 ^{a}	5.80 ^{a}	6.27 ^{a}	2.55 ^{d}	5.15 ^{bc}	8.05 ^{ab}
1 %A.A.	2.33 ^{c}	4.51 ^{bc}	5.67 ^{cde}	-0.52 ^{bc}	0.32 ^{b}	2.31 ^{bc}	3.31 ^{cd}	6.31 ^{bc}	6.51 ^{cd}
1 % E.A.	0.45 ^{c}	0.85 ^{d}	4.91 ^{de}	-2.33 ^{cde}	-2.08 ^{cd}	2.98 ^{bc}	2.35 ^{d}	4.71 ^{bc}	6.08 ^{a}
1.5 % A.A.	5.83 ^{b}	6.62 ^{b}	7.33 ^{cd}	0.55 ^{b}	0.65 ^{b}	2.98 ^{bc}	5.08 ^{abc}	6.03 ^{bc}	7.53 ^{abc}
1.5 % E.A.	2.29 ^{d}	1.34 ^{cd}	4.93 ^{de}	-1.63 ^{c}	-1.48 ^{cd}	2.90 ^{bc}	3.70 ^{cd}	4.35 ^{cd}	7.74 ^{a}
1%C.A.+ 1% A.A.	9.28 ^{a}	10.14 ^{a}	10.59 ^{ab}	-1.57 ^{c}	-2.71 ^{de}	2.40 ^{bc}	6.29 ^{a}	9.46 ^{a}	7.53 ^{abc}
1%C. A.+ 1% E.A.	6.38 ^{b}	7.60 ^{ab}	7.63 ^{cd}	-2.01 ^{cd}	-2.10 ^{cd}	3.67 ^{b}	3.56 ^{cd}	6.86 ^{b}	8.74 ^{bc}
1%C.A.+1.5% A.A.	9.64 ^{a}	7.48 ^{ab}	8.37 ^{bc}	-1.17 ^{bc}	-1.00 ^{bcd}	1.88 ^{bc}	6.03 ^{ab}	5.44 ^{bc}	7.16 ^{bc}
1%C.A.+1.5 % E.A.	0.52 ^{d}	3.20 ^{cd}	5.52 ^{de}	-1.76 ^{c}	-1.86 ^{cd}	2.59 ^{bc}	4.44 ^{bc}	4.00 ^{cd}	7.08 ^{bc}

*Significant differences between means ($p<0.01$) are expressed by different letters. The letters compare values in the same column.

Rocha and Morais (2003) reported that minimally processed apple slices were darker (lower L* values) in color and less green (higher a* values) at the third day of the 10 day storage when compared to the beginning values. A decrease in L* value and increase in a* value were indicatives of browning. Lozano *et al.* (1994) reported that enzymatic browning in the apple pulp of the Golden Delicious was related to degree of ripeness, temperature (3.5-31^{o}C), content of ascorbic acid and polyphenoloxidase activity.

3.1.3 Changes in b value

b values of sample were given at Table 3. during storage. The difference between treatments were found significant on b value ($p<0.01$). The lowest b values were submerged in SO_2 solution.

Table 3. b values of dehydrated apple cultivars during storage.

Treatments	Amasya			Golden delicious			Starkrimson delicious		
	Months								
	0	4	8	0	4	8	0	4	8
Water (Control)	24.19 ab	23.76 ab	25.44 ab	22.98 bc	24.51 abc	23.82 c	25.86 ab	25.51 ab	26.47 a
1000 ppm SO_2	15.72 d	17.56 c	21.55 e	22.39 bc	21.91 cd	21.68 d	20.40 e	22.25 cd	22.78 cdef
2000 ppm SO2	19.21 e	16.54 c	21.72 e	20.37 c	20.61 d	21.74 d	21.10 de	21.31 d	20.86 f
1 % C.A.	24.61 ab	25.53 a	25.09 abc	23.82 abc	26.37 a	26.01 ab	25.75 ab	24.84 abc	25.78 ab
1 %A.A.	22.02bcd	24.66 ab	25.72 a	24.14 ab	24.60 abc	25.75 abc	23.22 cd	25.94 ab	25.95 ab
1 % E.A.	25.26 a	25.87 a	25.11 abc	27.12 a	26.80 a	27.27 a	26.56 a	27.44 a	25.03 abc
1.5 % A.A.	22.22 bc	23.44 ab	24.82abcd	25.37 ab	26.42 abc	26.94 ab	24.62 abc	25.00 abc	24.51abcde
1.5 % E.A.	23.56 ab	24.00 ab	25.12 abc	25.42 ab	26.03 ab	27.57 a	26.78 a	26.05 ab	24.2 abcde
1%C.A.+ 1% A.A.	20.59 cd	22.90 ab	23.32 cde	24.64 ab	24.05 abc	26.52 ab	23.92 bc	25.00 abc	23.80 bcde
1%C. A.+ 1% E.A.	21.9 bcd	22.63 ab	22.98 de	23.67 abc	24.39 abc	24.90 bc	23.50 bc	24.24 bcd	22.29 ef
1%C.A.+1.5% A.A.	20.28 cd	24.06 ab	23.4 bcde	22.29 bc	23.26 bcd	25.76 abc	23.91 bc	24.72 abc	24.85 abcd
1%C.A.+1.5 % E.A.	20.62 cd	21.57 b	24.05 abcd	24.72 ab	24.49 abc	25.84 ab	23.57 bc	23.93 bcd	22.63 def

*Significant differences between means ($p<0.01$) are expressed by different letters. The letters compare values in the same column.

b value of apple chips was seen increasing during storage. This increase was slower for first 4 month, than last month. But increases of b value of apple chips dipped into SO_2 and 1% AA solution was found significant ($p<0.01$).
The color parameters L, a, and b were found to be significantly affected by dipping solution. But b values of samples were found meaningless. Similar results were obtained by Sapers and Douglas (1987) with several other cut apple cultivars. They suggested that enzymatic browning at cut surface of apple could be monitored by measuring changes in reflectance L* and a* values, and that b* values seemed to be unrelated to extend of browning.
Samples of apple dipped into SO_2 solution inhibits color deterioration before dehydration, resulting in apple chips with superior color compared to those dipped by other solutions.

3.2 Changes in browning index during storage

It can be seen Table 4 the lowest value were seen at chips which SO_2 treatment. This situation, preservation of color was found significant than the other solution. The highest absorbance value of sample was dipped into 1 %AA and 1.5%AA and water during storage. If these solutions include CA, preservation of these solutions may increase against to browning.
The difference between treatments and cultivars means were significant on browning index ($p<0.01$).
Degree of browning of apple chips was seen increasing during storage. At the beginning of storage, these values of dipped into AA were similar to control group. But this difference was increased at storage period. This can be expressed degradation product of AA and EA were caused browning.
Sodium sulphite was the most effective in preventing browning. Ascorbic acid and erythorbic acid (1%-1.5%) was not very effective as browning occurred within storage.
Sapers and Ziolkowski (1987) added erythorbic or ascorbic acid to eliminate the enzymatic browning of cut surface of apples in order to eliminate the use of sulphur dioxide from treatment prior to drying. Sulphur dioxide is a good color preservative of fresh fruits and vegetables, as it retards both enzymatic and non-enzymatic browning reactions, but it is extensive use in foods has been challenged, mainly for human health reasons. Borenstein (1965) compared L-Ascorbic Acid (LAA) and D-Ascorbic Acid (DAA- Erythorbic Acid) in experimental food systems and noted many chemical differences between the antioxidant

Table 4. Browning index of dehydrated apple cultivars during storage.

	Amasya			Golden delicious			Starkrimson delicious		
	Months								
Treatments	**0**	**4**	**8**	**0**	**4**	**8**	**0**	**4**	**8**
Water (Control)	0.083 ^{a}	0.077 ^{ab}	0.086 ^{cd}	0.033 ^{b}	0.032 ^{f}	0.058 ^{cd}	0.044 ^{bc}	0.041 ^{de}	0.045 ^{d}
1000 ppm SO_2	0.013 ^{d}	0.035 ^{c}	0.037 ^{e}	0.015 ^{cd}	0.030 ^{f}	0.038 ^{e}	0.026 ^{d}	0.032 ^{ef}	0.030 ^{e}
2000 ppm SO2	0.012 ^{d}	0.025 ^{c}	0.028 ^{e}	0.016 ^{cd}	0.028 ^{f}	0.037 ^{e}	0.021 ^{d}	0.029 ^{ef}	0.026 ^{e}
1 % C.A.	0.058 ^{b}	0.066 ^{b}	0.070 ^{d}	0.013 ^{d}	0.024 ^{f}	0.034 ^{e}	0.022 ^{d}	0.024 ^{f}	0.020 ^{e}
1 %A.A.	0.085 ^{a}	0.093 ^{a}	0.101 ^{b}	0.059 ^{a}	0.066 ^{b}	0.067 ^{bc}	0.031 ^{cd}	0.071 ^{bc}	0.072 ^{c}
1 % E.A.	0.060 ^{b}	0.065 ^{b}	0.070 ^{d}	0.021 ^{cd}	0.064 ^{bc}	0.073 ^{b}	0.046 ^{ab}	0.073 ^{bc}	0.072 ^{c}
1.5 % A.A.	0.095 ^{a}	0.093 ^{a}	0.123 ^{a}	0.058 ^{a}	0.063 ^{bc}	0.072 ^{b}	0.053 ^{a}	0.094 ^{a}	0.105 ^{a}
1.5 % E.A.	0.056 ^{b}	0.073 ^{ab}	0.086 ^{cd}	0.019 ^{cd}	0.075 ^{a}	0.089 ^{a}	0.055 ^{a}	0.067 ^{c}	0.069 ^{c}
1%C.A.+ 1% A.A.	0.038 ^{c}	0.074 ^{ab}	0.084 ^{cd}	0.013 ^{d}	0.051 ^{d}	0.051 ^{d}	0.038 ^{bc}	0.083 ^{ab}	0.086 ^{b}
1%C. A.+ 1% E.A.	0.048 ^{bc}	0.070 ^{b}	0.090 ^{c}	0.025 ^{bc}	0.044 ^{e}	0.050 ^{d}	0.041 ^{bc}	0.046 ^{d}	0.052 ^{d}
1%C.A.+1.5% A.A.	0.052 ^{b}	0.076 ^{ab}	0.079 ^{d}	0.034 ^{b}	0.055 ^{cd}	0.052 ^{d}	0.045 ^{ab}	0.077 ^{bc}	0.092 ^{ab}
1%C.A.+1.5 % E.A.	0.054 ^{b}	0.070 ^{b}	0.089 ^{c}	0.015 ^{cd}	0.054 ^{cd}	0.065 ^{bc}	0.045 ^{ab}	0.084 ^{ab}	0.093 ^{ab}

*Significant differences between means ($p<0.01$) are expressed by different letters. The letters compare values in the same column.

Table 5. L-ascorbic acid content of dehydrated apple cultivars during storage (mg/100 g).

	Amasya			Golden delicious			Starkrimson delicious		
	Months								
Treatments	**0**	**4**	**8**	**0**	**4**	**8**	**0**	**4**	**8**
Water (Control)	8.08 ^{d}	3.35 ^{d}	2.46 ^{e}	13.18 ^{g}	7.55 ^{f}	7.23 ^{d}	7.84 ^{f}	2.37 ^{d}	1.87 ^{bc}
1000 ppm SO_2	30.60 ^{d}	3.69 ^{d}	1.23 ^{e}	40.80 ^{g}	11.19 ^{f}	5.54 ^{d}	8.46 ^{f}	2.12 ^{d}	1.02 ^{c}
2000 ppm SO2	20.65 ^{d}	2.49 ^{d}	0.95 ^{e}	23.88 ^{g}	5.73 ^{f}	8.78 ^{d}	8.33 ^{f}	2.34 ^{d}	0.00 ^{c}
1 % C.A.	7.71 ^{d}	4.72 ^{d}	1.63 ^{e}	8.34 ^{g}	12.05 ^{f}	7.13 ^{d}	6.84 ^{f}	1.86 ^{d}	0.00 ^{c}
1 %A.A.	165.42 ^{c}	97.50 ^{bc}	4.05 ^{de}	206.47 ^{f}	69.47 ^{ef}	8.25 ^{d}	88.31 ^{e}	73.68 ^{b}	5.19 ^{abc}
1 % E.A.	263.68 ^{bc}	48.44 ^{cd}	6.27 ^{cde}	308.46 ^{e}	103.74 ^{ef}	9.49 ^{d}	120.65 ^{de}	32.95 ^{bc}	0.82 ^{c}
1.5 % A.A.	286.07 ^{bc}	124.52 ^{b}	12.00 ^{bcd}	541.04 ^{d}	113.09 ^{ef}	12.50 ^{d}	145.52 ^{cde}	75.07 ^{b}	9.07 ^{a}
1.5 % E.A.	393.03 ^{b}	144.52 ^{b}	11.55 ^{cd}	523.63 ^{d}	166.67 ^{de}	16.36 ^{cd}	156.72 ^{cd}	8.80 ^{cd}	1.75 ^{bc}
1%C.A.+ 1% A.A.	266.17 ^{bc}	168.54 ^{b}	12.92 ^{abcd}	871.89 ^{b}	465.53 ^{c}	75.77 ^{a}	131.84 ^{de}	48.32 ^{bc}	6.31 ^{ab}
1%C. A.+ 1% E.A.	273.63 ^{bc}	151.28 ^{b}	13.40 ^{abc}	726.37 ^{c}	251.19 ^{d}	24.59 ^{c}	195.27 ^{bc}	16.98 ^{bcd}	4.45 ^{abc}
1%C.A.+1.5%A.A.	687.81 ^{a}	299.26 ^{b}	21.47 ^{a}	1049.75 ^{a}	796.36 ^{b}	44.48 ^{b}	216.42 ^{b}	145.52 ^{a}	8.99 ^{a}
1%C.A.+1.5% E.A.	671.64 ^{a}	263.32 ^{a}	20.87 ^{ab}	1054.7 ^{a}	909.41 ^{a}	43.92 ^{b}	329.60 ^{a}	82.93 ^{b}	8.41 ^{a}

*Significant differences between means ($p<0.01$) are expressed by different letters. The letters compare values in the same column.

capacities of the two compounds. The antioxidant DAA has been shown to have less reducing capacity than LAA. Nevertheless, recommended uses of concentrations of the two reducing agents are similar.

The color of the apple slices treated with DAA was comparable to the color slices treated with the more expensive, LAA. In contrast, Sapers and Ziolkowski (1987) found LAA to be more effective than DAA in delaying the onset of darkening of Red Delicious and Winesap apple plugs held at room temperature.

Bolin and Steele (1987) used low oxygen pressure or sulphur dioxide processing to avoid the oxidative type of non-enzymatic browning which, as they showed, accounts for 60-70% of the total browning during storage.

3.3 Changes in ascorbic acid during storage

Ascorbic acid has been widely used as an antibrowning agent for processing of food. Content of ascorbic acid of dehydrated apple chips were shown Table 5. At the beginning of storage content of ascorbic acid of chips was changed according to dipping solution. Content of ascorbic acid were found 7.71-30.60mg/100g dipped into water, SO_2 and citric acid solution at the beginning of storage.

Content of ascorbic acid of chips were increased according to concentration of ascorbic and erythorbic acid. Present of citric acid in solutions, thanks to decreasing of pH, prevented degradation of ascorbic acid.
Dipping in SO_2 of fresh apple, were prevented of degradation ascorbic acid according to control group (Bhardjaw and Kaushal, 1990). Effect of different solution was found significant on ascorbic acid content ($p<0.01$).
During storage, content of ascorbic acid was reported decreasing. Loss of ascorbic acid content was found 59.5% at end of 4.th month and 92.7% at end of 8.th month. Effect of storage on ascorbic acid content was found significant ($p<0.01$).

4. CONCLUSION

In conclusion, sodium sulphite was the most effective in preventing browning. Ascorbic acid and erythorbic acid (1%-1.5%) was not very effective as browning occurred during storage. Golden delicious were determined suitable cultivar for dehydration.

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