The effect of pre-treatment methods on the quality of dehydrated candied Japanese quince fruits during storage

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Abstract Candied quince is one of the most popular processing products of Japanese quince (*Chaenomeles japonica*) in Latvia. During the storage of dehydrated fruit, the colour turns darker, thus negatively influence the overall quality and consumers' acceptability of the product. The aim of the present study was to evaluate the effectiveness of different anti-browning agents in combination with fruit blanching and soaking as a type of pre-treatment to preserve the colour of candied quince during 8-months storage. The fruit were harvested at various maturity stage (i.e. unripe, semi ripe and ripe) with the following pre-treatment using three anti-browning agents (L-cysteine, NATRAPHASE® ABAF and Natureseal® AS1). Hunter L (whiteness/darkness), a (redness/greenness) and b (yellowness/blueness) values were used to measure change in colour. These values were also used for calculation of the total colour change (ΔE^*). Considering blanching and soaking as a type of treatment. Best results were obtained with blanching treatment. L* values decreased significantly after dehydration, showing that the samples became darker, during the further 8-months storage, L* values increased, positively influencing the colour of the tested fruit. The data obtained using the Analytic Hierarchy Process Analysis revealed that 0.3% L-cysteine was the best for effective prevention of colour change during long-term storage among the tested agents.

Keywords Japanese quince fruits · Anti-browning agents · Pre-treatment · Quality

Introduction

Drying is one of the oldest and well-known processing methods used for preservation of fruits (Lüle and Koyuncu 2015). Drying increases the shelf life of fruit (Elmizadeh et al. 2017). Different methods are used for drying: sun or solar, freeze drying, drum drying, spray drying, foam mat and vacuum belt, convection air and superheated steam (tray, tunnel), osmotic drying, microwave (Ahmed et al. 2013). Combined method, involving convective pre-drying followed by vacuum-microwave finishing drying is recognized as a good drying method for fruits (Szychowski et al. 2018).

Physical appearance and colour attributes are important for dried fruits (Chong et al. 2013). The visual appearance of the dried products affects consumer acceptability. While purchasing, consumers pay the first attention to the product's colour and only after that they think about the shelf life and nutritional value (Adepoju and Osunde 2017). It was observed that the colour of dried candied quince fruit surface turns darker during storage. While fruits are processed at high temperature, a chemical reactions occur between amino acids and reducing sugars which generate different flavours and brown colour (Tamanna and Mahmood 2015). The colour changes are caused by enzymatic or Maillard reactions among phenol compounds during food processing. The enzymatic reactions change the colour of dehydrated fruit surface to brown or darker colour due to the oxidation of phenols to o-quinones (melanoidin, a brown and polymeric pigment). Dehydrated fruits contain reducing sugars (glucose, sucrose, fructose and carbohydrates), which during drying process could be involved in the Maillard reactions taking place by presence of amino acids. The end product of the Maillard reaction a brown

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pigment melanoidin (Chong et al. 2013; Coimbra et al. 2011).

Many studies verified the use of different pre-treatment methods included lemon juice, ascorbic acid dip, salt solution, honey dip, osmotic pre-treatment, blanching, chilling and freezing (steam and water) before drying (Motevali and Hashemi 2017; Adepoju and Osunde 2017; Landim et al. 2016; Hedayatzadeh and Chaji 2016; Lewicki 1998). Doymaz (2004) was studied the effects of different pre-treatment processes for the prevention of colour changes: dipping in combination of potassium metabisulphide and alkaline ethyl oleate solutions. In scientific literature many facts have been mentioned for prevention of apple browning before drying to use anti-browning agents, such as 0.5% ascorbic acid solution; 0.3% L-cysteine solution; 0.1% 4-hexyl resorcinol solution; 0.5% sodium metabisulfite solution, mixed and blanching in hot water at 85 °C, which has produced good results (Adepoju and Osunde 2017; Jokić et al. 2009). In food industry before drying sulphur dioxide frequently is used as an anti-browning agent to prevent enzymatic or no enzymatic browning reactions, as well as to provide invariable colour during storage (Salur-Can et al. 2017; Sen et al. 2015; Guideline and Consumption 2012).

Fruit of Japanese quince (*Chaenomeles japonica*) are often used in the production of dehydrated candies. Quince fruit contain high level of beneficial health nutrients, minerals and have a pleasant aroma (Bieniasz et al. 2017; Seglina et al. 2009). However, a substantial decrease of vitamin C and colour changes during storage of dehydrated candied quince fruits were observed, which is an obstructive factor to sell the product on the commercial network. Despite the extensive literature data regarding the browning of fruit and vegetable, there are only a few shreds of evidence suggesting a positive/beneficial effect on colour maintenance of dehydrated candied quince fruit during storage. The aim of this study is to verify the pre-treatment (soaking and blanching) and several anti-browning agents (L-cysteine, NATRAPHASE® ABAF and Natureseal® AS1) influence on the dehydrated candied Japanese quince (DCJQ) quality changes during 8 month of storage.

Materials and methods

The research has been carried out at the Processing and Biochemistry Unit of the Institute of Horticulture, Latvia University of Agriculture. In this study Japanese quince (*C. japonica*) genotype C-9; C-14; and C-44 fruit mix was used. Following harvesting the Japanese quince fruits were sorted by degree of readiness (unripe, semi ripe and ripe), according to the degree of readiness. The degree of readiness was defined visually by colour. The quince fruits

were cut into pieces and pre-treated by two methods. The first method was quince blanching in 50% sugar syrup at 80 °C temperature for 10 min, then mixture put on the sieve and syrup strained off, quince pieces were placed in polymer boxes, cooled and stored frozen in refrigerator at -18 ± 1 °C. The second method was soaking of quince pieces for 10 min in sugar syrup at 60 °C temperature, further fruits were collected and placed in polymer boxes, cooled down till room temperature (22 ± 1 °C) and next day put in refrigerator at temperature -18 ± 1 °C. The above mentioned Japanese quince fruit treatment methods without added anti-browning agents (e.g. L-cysteine, NATRAPHASE® ABAF and Natureseal® AS1) were used as control examination. Before drying the refrigerated quince fruits were defrosted, those stored with syrup were put on the sieve and syrup strained off followed by drying of samples in microwave dryer “Musson-1” and dehydrated candied Japanese quince fruits obtained. Dehydrated candied Japanese quince fruits were packed by 0.250 g in polymer PROPAFILM™ RPG35 bags (thickness 25 µm), which was inserted in paper bags with polymer windows. The mass of the dried product in each bag was 100 ± 5.0 g. Packed, candied fruits were stored at a room temperature ($20 \pm$ °C); relative air humidity during 8-month of storage was $\sim 60 \pm 2\%$. Samples (in 3 repetitions) were analysed at 0-day and in a 4 and 8 months’ time.

Various anti-browning agents could be used for fruit pre-treatment. For the prevention of dehydrated candied Japanese quince browning during storage, before drying the cut quince fruits were pre-treated with sugar syrup (concentration of 50%) with addition of different anti-browning agents added:

- L-cysteine hydrochloride monohydrate 0.3% (Sigma-Aldrich);
- complex inhibitors NatureSeal® AS1, 4.5% (AgriCoat Ltd., Great Shefford, UK);
- innovative processing agent NATRAPHASE® ABAF, 3% (Natural Biotechnology Sprl. Belgium).

The changes of DCJQ surface **colour** during storage time were measured by CIE L*a*b* colour system using Colour Tec PCM/PSM Bench Top Models-45 device. The sample of product by mass of 15 g was placed in a glass container (diameter 30 mm). The colour measurements of three identical samples were performed in 10 reiterations for each and colour values L*, a* and b* defined. The colour difference among each measured sample was expressed as yellowness index YI and total colour difference ΔE^* , as reported by (Nagle et al. 2016).

The content of **vitamin C** was determined by standard method EN 14130:2003 “Foodstuffs—Determination of vitamin C by HPLC”. **Total phenolic** (TP) content was

determined by the photometric method using Folin–Ciocalteu reagent by Singleton et al. (1999). Additionally, for all dehydrated candied Japanese quince samples the moisture content was determined according to the Standard ISO 6496:1999 and all results have been expressed on a dry-matter basis (DW).

Statistical analysis

Experimental data processing was carried out by Multi-variate General Linear Model procedure SPSS 17 software package. The mean arithmetic value and standard deviation were calculated for the obtained results. Closeness of the relationship between the parameters was determined by analysis of Pearson correlation coefficient, Tukey's multiple range test was used in the clarification of significant differences ($p < 0.050$) among the studied samples.

Analytic Hierarchy Process (AHP) was used to evaluate the changes of DCJQ surface colour during storage time with descriptive method. The main quality properties of candied quince fruit's are colour (characterized by L^* value for lightness), vitamin C and total phenol content, which were accepted as basic criteria for valuation by relative significance scale for intensity of importance 1–7. To estimate the uppermost criteria of DCJQ quality by importance, the lowest value was assigned to L^* —1, next to vitamin C—3, and to total phenols—7.

As suggested in literature the priority coordinates' vectors were calculated according to Analytical Hierarchy process (AHP) (Saaty 2008).

The dynamics of experimentally determined quality parameters of Japanese quince fruit's surface during storage (L^* , YI, vitamin C and total phenols content) were calculated by formula:

$$\frac{X_{fe} - X_{fo}}{X_{fe}} \cdot 100\%,$$

where X_{fe} —values of parameters before storage; X_{fo} —values of parameters following 8 months of storage.

Results and discussion

The moisture content of different dehydrated candied Japanese quince (DCJQ) samples is shown in Table 1. The difference in moisture content among the examined samples is due to different pre-treatment techniques (blanching and soaking) applied as well as fruit origin (size and genotype).

Surface colour

Surface colour is the main characteristic of fruit quality, playing a dominant role in consumer acceptance. Yellow colour is an important attribute of Japanese quince fruit candy quality which occurred on the surface (Nagle et al. 2016). Considering that consumers often choose products by their appearance, for the assessment of dehydrated candied Japanese quince fruits, the surface colour intensity L^* and YI values were determined. The results of blanched dehydrated candied Japanese quince fruit surface colour L^* and YI values are summarized in Table 2. L^* values of DCJQ samples measured of different maturity stages of fruits and treated by blanching were disparate ($p = 0.001$).

The YI and L^* values were higher of dehydrated candied Japanese quince fruit surface produced from ripe fruits to compare with semi ripe and unripe fruits. Studies also showed that fruit ripeness stage at processing had a significant effect ($p < 0.05$) on the quality of apple and pear slices (Giacalone and Chiabrando 2013; Oms-Oliu et al. 2008). Unripe fruits contain more phenolic compounds, organic acids and amino acids compared to ripe fruits (Vila et al. 2003; Ros et al. 2004; Rop et al. 2011). Phenolic compounds and polyphenol oxidases are responsible for enzymatic reactions in fruit processing. Positive correlation between content of polyphenols and enzymatic browning has been found (Holderbaum 2010). Several studies show that browning of fruit tissue is mostly due to changes in lightness (L^*) of the pulp and may be caused by the

Table 1 Moisture content of the dehydrated candied Japanese quince fruits, (%)

Maturity stage	Pre-treatment method		
		Blanching	Soaking
R	C	15.0 ± 0.4	22.0 ± 1.1
	L cys	14.7 ± 0.2	23.5 ± 1.7
	ABAF	21.2 ± 0.9	22.4 ± 0.8
	NS	15 ± 0.3	27.2 ± 1.2
SR	C	19.3 ± 0.8	12.3 ± 0.5
	L cys	17.7 ± 0.4	14.3 ± 0.3
	ABAF	29.2 ± 0.7	13.3 ± 0.9
	NS	20 ± 0.5	13 ± 0.5
UN	C	18.8 ± 0.4	28.9 ± 0.4
	L cys	21 ± 0.8	25.9 ± 0.8
	ABAF	18.8 ± 0.2	18.6 ± 1.6
	NS	20.0 ± 0.9	22.3 ± 1.0

The data are indicated by standard deviations (n = 3)

C—control sample, L cys—0.3% L cysteine, ABAF—3% NatrapHase™ Abaf, NS—4.5% NatureSeal® AS1

Maturity stage: R ripe, SR semi ripe, UR unripe

Table 2 Dynamics of L* value and yellowness index YI during storage of DCJQ

Pre-treatment method	Samples	Storage time, months			
		0		8	
		L*	YI	L*	YI
Blanched	R C	57.59 ± 1.0	66.55 ± 1.1	48.04 ± 1.1	60.58 ± 1.4
	R L cys	52.01 ± 0.8	61.28 ± 1.2	50.63 ± 1.2	63.67 ± 0.9
	R ABAF	51.60 ± 1.1	61.18 ± 0.7	46.96 ± 0.6	59.23 ± 1.0
	R NS	50.87 ± 0.9	59.68 ± 1.9	47.06 ± 1.9	59.50 ± 1.2
	SR C	54.81 ± 0.8	65.42 ± 0.8	47.08 ± 0.8	59.21 ± 1.5
	SR L cys	51.76 ± 1.1	62.11 ± 1.1	50.67 ± 1.1	63.40 ± 1.7
	SR ABAF	49.86 ± 1.2	59.65 ± 1.0	46.51 ± 1.0	58.28 ± 2.3
	SR NS	54.57 ± 0.9	65.43 ± 0.9	36.38 ± 0.9	47.92 ± 1.4
	UR C	48.82 ± 0.6	57.03 ± 0.5	38.82 ± 0.5	49.97 ± 1.1
	UR L cys	45.56 ± 0.8	54.56 ± 1.0	38.50 ± 1.0	49.53 ± 1.0
	UR ABAF	48.43 ± 1.3	55.73 ± 1.4	40.66 ± 1.4	51.31 ± 1.1
	UR NS	53.06 ± 0.8	62.36 ± 0.8	37.66 ± 0.8	48.78 ± 1.4
Soaked	R C	51.69 ± 1.0	63.90 ± 0.6	45.37 ± 1.4	55.42 ± 1.8
	R L cys	53.28 ± 0.8	53.50 ± 0.5	46.68 ± 0.8	57.95 ± 0.5
	R ABAF	49.59 ± 0.7	61.13 ± 0.7	41.77 ± 1.0	38.14 ± 0.6
	R NS	50.06 ± 0.9	59.7 ± 0.8	42.01 ± 1.4	52.14 ± 0.9
	SR C	48.65 ± 0.7	58.66 ± 0.6	40.79 ± 1.4	51.21 ± 0.9
	SR L cys	50.24 ± 0.8	58.97 ± 1.0	44.08 ± 3.5	54.63 ± 0.7
	SR ABAF	49.54 ± 0.8	59.93 ± 0.4	43.62 ± 1.4	53.8 ± 0.6
	SR NS	54.03 ± 0.4	66.25 ± 0.8	41.24 ± 1.9	52.26 ± 0.4
	UR C	48.59 ± 0.8	51.18 ± 0.5	36.24 ± 1.0	45.3 ± 1.1
	UR L cys	45.29 ± 1.8	53.05 ± 0.7	39.56 ± 2.0	49.5 ± 0.6
	UR ABAF	41.35 ± 1.4	48.95 ± 0.9	36.47 ± 0.9	45.63 ± 1.3
	UR NS	40.84 ± 1.2	49.44 ± 0.6	36.71 ± 1.3	46.17 ± 0.6

The data are indicated by standard deviations (n = 3)

C—control sample, L cys—0.3% L cysteine, ABAF—3% NatrapHase™ Abaf, NS—4.5% NatureSeal® AS1

Maturity stage: *R* ripe, *SR* semi ripe, *UR* unripe

enzymatic action of catechol oxidases, which is the most common polyphenol oxidises in apples (Wu et al. 2012; Krasnova et al. 2013). Temperature in the drying chamber of DCJQ was about 65 °C, at such temperature Maillard reaction between amino acids and reducing sugars is possible, which could have an effect on the foods quality, including colour and nutrition value (Tamanna and Mahmood 2015).

A study ascertained that quince candied fruit ‘Lichtar’ L* value was 63.7 and hybrid clone C47 respectively 63.77 (Rubinskienė et al. 2014). In the present study the statistical data analysis showed that values of YI among analysed samples substantially did not differ ($p = 0.052$).

The results of DCJQ in sugar syrup soaked fruit’s surface colour component L* and YI values are summarized in Table 2. L* values of DCJQ samples obtained from fruits of different maturity stages and treated by soaking in 50% sugar syrup were different ($p = 0.001$). Fruit ripeness

not only affects the physicochemical property of raw products, but also influences the sub-processing and product quality (Williams and Benkeblia 2018; Wang et al. 2017).

The results showed that the colour of ripe Japanese quince fruit can be characterised as bright yellow, however, the dehydration has resulted in significant reduction of colour intensity. Concerning the blanching as a type of pre-treatment, should be noted that almost all L* values were decreased significantly after dehydration, showing that the samples became darker. However, during the further 8-months storage, the L* values increased, positively influencing the colour of tested fruit. Among the tested anti-browning agents, the 0.3% L-cysteine was shown to be effective in prevention of colour change during long-term storage compared to other means. Considering the values obtained after soaking, the same tendency may be observed, indicating that the 0.3% L-cysteine followed by

3.0% NATRAPhASE[®] ABAF and 4.5% NatureSeal[®] AS1 are the most promising tools in ensuring the high quality of stored Japanese quince fruit. Comparable results were obtained by Jokić et al. (2009), reporting that apple slices pre-treated those in 4-hexyl resorcinol followed by blanching in hot water had minimal colour change. In addition, the same results were obtained by Rojas-Graü et al. (2008), indicating on positive effect of 1% N-acetylcysteine in the prevention of fresh-cut apple slices quality loss. Yellowness is a main characteristic of fruit quality which plays a dominant role in consumer acceptance (Nagle et al. 2016).

Total colour difference ΔE^* of DCJQ samples is calculated between L^* , a^* , b^* values before storage and following 8 months of storage, the results are demonstrated in Fig. 1.

It has been reported previously that the discolouration and browning of the products are considered to be an undesirable process which caused by various chemical reactions, including Maillard condensation of hexoses and amino components, pigment destruction, and phenol polymerization (Adams and Brown 2007). To preserve the colour of the products combined techniques could be applied. Total colour difference ΔE^* , which is a combination of parameters L^* , a^* and b^* values, is a colorimetric technique extensively used to characterize the variation of colours depending on processing conditions (Kortei et al. 2015). In this study, ΔE^* values were calculated in relation to the initial 0-month period of storage (control DCJQ). A larger ΔE^* indicates greater colour change from the reference DCJQ samples. It has been proposed that ΔE^* values less than 1 to be considered as not detectable by the human eye, while colour difference $3.3 \Delta E^* > 1$ can be distinguished by a proficient operator but were considered clinically acceptable. In addition, ΔE^* representing the values higher than 3.3 to be detectable by non-proficient persons and were therefore considered clinically unacceptable (Sarkis 2012). According to Fig. 1, ΔE^* of all

samples valued higher than 2, indicating great visible colour difference in samples before and after drying. By comparing all pre-treated and control samples, it was generally found that ΔE^* values after 8-month storage were significantly higher in ripe, semi ripe, and unripe fruit which before storage were blanched and pre-treated with NS—4.5% NatureSeal[®] AS1. While considerable lower values were found for ripe and semi ripe fruit before dehydration those were soaked using the 50% sugar syrup. A statistically ($p < 0.001$) and more positive effect has been achieved when 0.3% L cysteine both for ripe and semi ripe fruit was applied. The ΔE^* corresponding the values from 3.2 to 11.7 and from 3.8 to 12.8, respectively. Taking into consideration the other anti-browning agents, a comparable positive effect was achieved exclusively combining the NS—4.5% NatureSeal[®] with the fruit soaking using the 50% sugar syrup. The values within this type of pre-treatment fluctuated in the range of 4.3 to 11.7 for ripe fruit, while 3.8 to 12.8 for semi ripe fruit. A similar results had been reported by (Pace et al. 2015; Pongsakul et al. 2006), where L-cysteine was found to be the most potent anti-browning agent.

Phenolic compounds and vitamin C

Phenolic compounds and vitamin C could be a major determinant of antioxidant potentials of Japanese quince. Phenolic compounds are a large group of organic substances which create quince taste and aroma. The number of phenolic compounds are susceptible to heating and are lost during drying process. Food processing technology and storage, could also impact the variation of natural antioxidants by enhancing enzymatic reactions (Mediani et al. 2014). The changes in vitamin C and total phenol content in the sugar syrup blanched DCJQ after drying and during 8-month storage are summarized in Table 3.

Substantial differences were observed in the content of vitamin C in DCJQ samples treated by various anti-

Fig. 1 The changes in total colour difference (ΔE^*) of DCJQ during 8 months storage. The data are indicated by standard deviations ($n = 3$). C—control sample, L cys—0.3% L cysteine, ABAF—3%

NatrapHaseTM Abaf, NS—4.5% NatureSeal[®] AS1. Maturity stage: R ripe, SR semi ripe, UR unripe

Table 3 The dynamics of vitamin C and total phenol content DCJQ (with sugar syrup blanched) during storage

Samples (blanched in syrup)	Storage time			
	0		8 months	
	Vitamin C	Total phenol	Vitamin C	Total phenol
R C	66.0 ± 1.1 ^{dA}	875.1 ± 9.1 ^{dB}	10.8 ± 0.8 ^{dB}	906.6 ± 9.9 ^{dA}
R L cys	105.1 ± 2.1 ^{cA}	1031.8 ± 32.3 ^{cB}	56.1 ± 3.1 ^{cB}	1086.4 ± 9.4 ^{cA}
R ABAF	1292.6 ± 5.5 ^{bA}	1462.5 ± 33.2 ^{bB}	190.9 ± 6.3 ^{bB}	1609.8 ± 33.3 ^{bA}
R NS	1124.5 ± 27.0 ^{aA}	1426.3 ± 25.3 ^{aB}	214.6 ± 8.6 ^{aB}	1584.4 ± 27 ^{aA}
SR C	39.0 ± 0.3 ^{dA}	1073.8 ± 18.4 ^{dB}	9.7 ± 1.2 ^{dB}	1120.4 ± 10.8 ^{dA}
SR L cys	102.0 ± 1.3 ^{cA}	1279.8 ± 24.3 ^{cB}	60.5 ± 4.0 ^{cB}	1334.8 ± 8.5 ^{cA}
SR ABAF	1699.7 ± 28 ^{bA}	1935.6 ± 21.1 ^{bB}	193.7 ± 3.9 ^{bB}	2112.4 ± 15.4 ^{bA}
SR NS	2024.0 ± 19.0 ^{aA}	1543.5 ± 29.2 ^{aB}	250.0 ± 4.6 ^{aB}	1734.2 ± 14.1 ^{aA}
UR C	82.1 ± 1.2 ^{dA}	949.2 ± 11.8 ^{dB}	14.7 ± 7.8 ^{dB}	985.2 ± 10.2 ^{dA}
UR L cys	157.6 ± 15.6 ^{cA}	1009.0 ± 14.2 ^{cB}	53.4 ± 8.4 ^{cB}	1071.4 ± 10.1 ^{cA}
UR ABAF	1250.8 ± 44.9 ^{bA}	1652.5 ± 38.3 ^{bB}	98.6 ± 8.2 ^{bB}	1791.6 ± 29.3 ^{bA}
UR NS	2664.5 ± 37.2 ^{aA}	1536.7 ± 37.4 ^{aB}	121.6 ± 9.9 ^{aB}	1673.8 ± 32.4 ^{aA}

Means (made from 3 replicates) followed by different small letters within the same column and indices, are significantly different at the 0.05 level (differences between pre-treatment). Mean (made from 3 replicates) followed by different capital letters within the same row and pre-treatment, are significantly different at the 0.05 level (differences between storage time)

Total phenol content, mg gallic acid 100 g⁻¹ DW. Vitamin C mg 100 g⁻¹ DW

The data are indicated by standard deviations (n = 3)

C—control sample, L cys—0.3% L cysteine, ABAF—3% NatrapHaseTM Abaf, NS—4.5% NatureSeal[®] AS1

Maturity stage: R ripe, SR semi ripe, UR unripe

browning agents ($p < 0.001$). The content of vitamin C in samples pre-treated using the anti-browning agents NATRAPHASE[®] ABAF and NatureSeal[®] AS1 was more than 10 times higher compared to control sample. Anti-browning agent NatureSeal[®] AS1 is patented dry anti-browning agent, which contains mineral substances and ascorbic acid (Lidster et al. 2011). Dipping in Natureseal[®] A1 solutions are preferable for the transport of sufficient amounts of ascorbic acid into the cut apple pieces over a relatively short dipping time. Within dipping times of 0.5–3 min, the initial residual ascorbic acid content in fresh cut apple pieces reaches about 200 to about 500 mg per 100 g⁻¹ of apple mass. Scientists studied fresh-cut apple wedge treatment by NatureSeal[®] AS1 and AS5, and established, that total phenolic content remained relatively constant over the 15-d storage period (Krasnova et al. 2017; Röbke et al. 2009). It has been demonstrated that the content of phenolic compounds of dried candied quince was reduced on average by 4.7% in products after 2 months of storage, but at the end of the study the total content of phenolic compounds reduced on average by 17% (Seglina et al. 2009).

The total phenol and vitamin C contents in the DCJQ fruits during storage time varied significantly in all tested samples ($p = 0.001$ and $p = 0.0012$). The total phenol content in sugar syrup blanched DCJQ samples during

storage substantially decreased ($p = 0.004$). As a result of Maillard reactions an increase of total phenolic compound values was observed in all tested samples. When vegetables are treated at high temperature, the pro-oxidant activity decreases and antioxidant activity increases due to the formation of Maillard reaction products (MRPs). Such antioxidant activity of the MRPs comes from the high molecular weight brown compounds that are formed in the advanced stages of the reaction (Tamanna and Mahmood 2015). During 8-month storage of DCJQ samples, the content of vitamin C in ripe quince control (RC) sample decreased by 83.7%, in semi ripe (SRC) by 75.1% and in unripe by 82%. The content of vitamin C substantially decreased using all anti-browning agents. A study indicates vitamin C content of NatureSeal[®] AS1 treated fresh cut apple wedges decreased substantially ($p < 0.001$) during storage (Röbke et al. 2009).

The dynamics of total phenol and vitamin C content in the soaked samples of DCJQ during storage are summarized in Table 4.

The results show that the highest content of phenol after 8-months storage was observed for ripe samples those before dehydration were soaked in sugar syrup and treated with 4.5% NatureSeal[®] AS1 (R NS). Comparable results, however, were obtained for semi ripe and unripe samples pre-treated those with 4.5% NatureSeal[®] AS1 (SR NS and

Table 4 Dynamics of vitamin C and total phenol content of the DCJQ (in sugar syrup soaked) during storage

Samples (soaked in syrup)	Storage time			
	0		8 months	
	Vitamin C	Total phenol	Vitamin C	Total phenol
R C	66.2 ± 3.7 ^{dA}	495.5 ± 14.2 ^{dB}	17.3B ± 5.1 ^{dB}	551.0 ± 8.8 ^{dA}
R L cys	103.8 ± 12.6 ^{cA}	652.2 ± 13.2 ^{cB}	72.1B ± 4.2 ^{cB}	717.0 ± 9.3 ^{cA}
R ABAF	1102.6 ± 14.3 ^{bA}	1183.3 ± 11.2 ^{bB}	282.2 ± 5.6 ^{bB}	1337.4 ± 12.7 ^{bA}
R NS	2027.9 ± 27.1 ^{aA}	1749.7 ± 20.1 ^{aB}	324.8 ± 6.5 ^{aB}	1966.9 ± 18.7 ^{aA}
SR C	35.5 ± 0.9 ^{dA}	568.8 ± 42.9 ^{dB}	13.0 ± 3.2 ^{dB}	639.8 ± 9.6 ^{dA}
SR L cys	97.9 ± 13.3 ^{cA}	735.7 ± 40.7 ^{cB}	47.6 ± 3.1 ^{cB}	818.0 ± 10.5 ^{cA}
SR ABAF	1348.4 ± 16.3 ^{bA}	1326.7 ± 36.2 ^{bB}	136.6 ± 1.2 ^{bB}	1449.9 ± 12.2 ^{bA}
SR NS	1860.7 ± 18.4 ^{aA}	1542.0 ± 34.2 ^{aB}	203.3 ± 3.1 ^{aB}	1719.4 ± 17.1 ^{aA}
UR C	96.5 ± 7.9 ^{dA}	573.3 ± 10.0 ^{dB}	15.9 ± 6.7 ^{dB}	655.4 ± 12.4 ^{dA}
UR L cys	168.0 ± 16.5 ^{cA}	622.0 ± 7.9 ^{cB}	89.0 ± 5.8 ^{cB}	678.5 ± 8.1 ^{cA}
UR ABAF	1247.7 ± 17.4 ^{bA}	1260.5 ± 13.1 ^{bB}	149.0 ± 4.1 ^{bB}	1438.4 ± 23.0 ^{bA}
UR NS	2743.6 ± 20.8 ^{aA}	1596.9 ± 21.1 ^{aB}	376.2 ± 3.3 ^{aB}	1775.7 ± 21.2 ^{aA}

Means (made from 3 replicates) followed by different small letters within the same column and indices, are significantly different at the 0.05 level (differences between pre-treatment). Mean (made from 3 replicates) followed by different capital letters within the same row and pre-treatment, are significantly different at the 0.05 level (differences between storage time)

Total phenol content, mg gallic acid 100 g⁻¹ DW. Vitamin C mg 100 g⁻¹ DW

The data are indicated by standard deviations (n = 3)

C—control sample, L cys—0.3% L cysteine, ABAF—3% NatrapHaseTM Abaf, NS—4.5% NatureSeal[®] AS1

Maturity stage: R ripe, SR semi ripe, UR unripe

UR NS), where phenol content corresponding to 1719.4 and 1775.7 mg gallic acid 100 g⁻¹ DW, respectively. Considerably lower level of phenol was observed for samples those before dehydration were pre-treated with 3% NatrapHaseTM ABAF (SR ABAF), representing the values in the range of 1337.4–1438.4 mg gallic acid 100 g⁻¹ DW. However, these values to be significantly higher than those obtained for control and with 0.3% L cysteine treated fruit, representing the values in the range of 551.0–655.4 mg gallic acid 100 g⁻¹ DW and 678.5–818.0 mg gallic acid 100 g⁻¹ DW, respectively. Differences between the content of phenol in Japanese quince fruit may be due to an influence of bioactive constituents (e.g. ascorbic acid and minerals) present in the blend of anti-browning mixes which prevented the phenolic compounds from further oxidizing. Moreover, it has been proposed that in particular Mallard reaction products could influence the oxidation of phenols during long-term fruit storage (Tamanna and Mahmood 2015). Comparable results were obtained concerning the content of vitamin C in the tested sample. As it can be seen, higher concentration of vitamin C was found in soaked DCJQ samples those prior to dehydration were pre-treated with 4.5% NatureSeal[®] AS1. The amount of vitamin C in the tested samples after 8-month storage was in the range of 203.3–376.2 mg 100 g⁻¹ DW.

Analytic hierarchy process analysis (AHP)

AHP was used to figure out the most appropriate method for the processing of Japanese quince fruit. For AHP analysis the significance vectors were set based on the DCJQ quality indices L * value, vitamin C and total phenol. The most important criterion is the lowest value. The vectors have the following values: L * value = 0.09, vitamin C = 0.24 and total phenol = 0.67. The data analysis did not include the absolute values of the indicators, but their changes during the 8 months of storage. The results of the L * value, vitamin C and total phenol changes were expressed as a percentage. Results of AHP analysis assessment are summarized in Fig. 2.

Comparing the results from AHP analysis, it is evident that the lowest priority levels are attributed to the samples those were blanched and then pre-treated with 0.3% L-cysteine. As it seen, the priority levels for this type of pre-treatment were found in the range of 0.03–0.15. While for soaking and pre-treatment with L-cysteine these values were in the range of 0.06–0.13. Considering the data obtained using the NATRAPHASE[®] ABAF and NatureSeal[®] AS1, it is seen that these methods to be found less effective in the prevention the quality loss of Japanese quince during long-term storage. Based on the results

Fig. 2 DCJO pre-treatment evaluation by AHP analyses. C—control sample, L cys—0.3% L cysteine, ABAF—3% NatrapHase™ Abaf, NS—4.5% NatureSeal® AS1. Maturity stage: R ripe, SR semi ripe, UR unripe

obtained, it can be concluded that the blanching of the Japanese quince fruit with the further pre-treatment with L-cysteine was found to be an effective anti-browning technique with a good potential.

Conclusion

The surface colour of dehydrated candied Japanese quince is the major reason for consumer's choice to purchase this product. The value of total colour difference ΔE^* during storage can be reduced by using pre-treatment of fresh-cut quince fruits with anti-browning agent L-Cysteine hydrochloride monohydrate (0.3%). The degree of Japanese quince (*C. japonica*) fruit readiness is an important factor in dehydrated candied Japanese quince production process to provide quality, included colour decrease during storage. Total phenol and vitamin C content in hot sugar syrup blanched dehydrated candied Japanese quince is substantially higher than in syrup soaked samples. The assessment of dehydrated candied Japanese quince in general should be carried out by performing sensory (visual colour, texture, aroma and taste) evaluation following 8 month of dehydrated product storage.

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