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Original scientific paper

Fig freezing in sugar solutions: quality, phenolics composition and sensory properties during storage

Abstract

The effect of fig freezing in sugar solution on fig's quality and sensory traits as well as phenolic content during storage was examined. Fresh figs were frozen without any treatment (control - CON), in sucrose solution (30%) (SUC) and sucrose solution (30%) with ascorbic acid (2%) (SUCAA), and stored at -18 ^{0}C for 210 days. Samples were analyzed every seventy days for pH, total soluble solids (TSS), sugars and phenolics composition, skin and pulp color, and they were sensorially evaluated. According to ANOVA, storage time showed significant impact on more analyzed parameters than freezing conditions. CON and SUC had the highest TSS, what was also sensorially detected. SUCAA was evaluated with the lowest scores for sweetness and typical fig flavor followed by the highest score for off-taste, off-flavor and off-odor. Contrary to TSS, individual sugars and phenolics were the lowest in CON. SUCAA showed the most brightener skin and the reddest pulp measured by colorimeter, and sensorially it obtained the highest scores for skin and pulp color. Storage time caused TSS and pH decrease, what reflected sensorially as a decrease of fig taste and flavor, as well as the appearance of off-taste, off-flavor and off-odor was also observed. Contrary, individual sugars and phenolics showed increase during storage, and the lowest amounts were present in CON. In conclusion, after 140 days all figs noticeably lost their desirable attributes, where CON fig was sensorially the best evaluated and SUCAA gained the lowest scores.

Keywords: *fig freezing, sugar solution, quality, sensory properties, storage*

Introduction

Production of figs (*Ficus carica* L.) in Croatia is mostly located in coastal area and is very low, only 995 T as average yield in the last five years (FAOSTAT, 2021). Nevertheless, it is very popular and desirable fruit due to its peculiar sensory properties and high nutritional and biological values (Mawa et al., 2013). Figs are a rich source of minerals, vitamins, dietary fiber, organic acids, and sugars, mainly fructose and glucose (Mawa et al., 2013). Moreover, figs are abundant with health-promoting compounds such as phenolic acids and flavonoids. Hence, many authors examined its composition and reported the presence of chlorogenic, protocatechuic, galic, ellagic and vanillic acids, luteolin-3,7-di-*O*-glucoside, luteolin-7-glucoside, apigenin-7-*O*-rutinoside, quercetin-3-rutinoside, quercetin-3-glucoside, quercetin-3-acetylglucoside, cyanidin-3-*O*-rutinoside, epicatechin and catechin among others (Veberic et al., 2008; Russo et al., 2014; Pereira et al., 2017). However, figs as seasonal and highly perishable climacteric fruit have a limited postharvest lifespan (Flaishman et al., 2008). Therefore, its consumption in fresh state is limited with the harvest season, what implies the needs for its processing. Drying (Slatnar et al., 2011; Russo et al, 2014) or jam processing (Levaj et al, 2010; Petkova et al., 2019) are the common preservation procedures to prolong their availability on the market. Freezing is not so common strategy for figs preservation, but generally, as it presents the conventional method of preservation, it is very convenient due to unnecessity of chemical preservatives, it is the least long-lasting food preservation method as well it least affects the alteration of fruit's nutritional and sensory values. Nevertheless, during freezing and frozen storage fruit quality deteriorates when compared to the raw materials due to formation of ice which can cause cell damage, freeze concentration, textural alterations and other complex physical, chemical as well as bio-

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chemical processes, e.g., various oxidative reactions (Van der Sman, 2020). Therefore, different treatments prior to freezing have been studied in different fruits with purpose to overcome shortcomings of freezing. For example, immersion of fruits in sugar syrup showed protective effect, especially for frozen berries during storage (Barbosa-Cánovas et al., 2005).

This study aimed to examine the effect of freezing figs in sucrose syrup with or without the addition of L-ascorbic acid on figs quality and sensory traits as well as on the phenolics and sugars composition during 7 months' storage at -18 °C.

Materials and methods

Plant material

Fig fruit (*Ficus carica* L., cv. Bjelica; yellow-green epidermis, red pulp) (Figure 1) used in this experiment originated from a domestic production in an old orchard on island Brač (Dalmatia, Croatia). The figs (approximately 10 kg) were hand-picked in ripe stage what was determined subjectively by palpation (Levaj et al., 2010). Only undamaged and healthy fruits were selected, washed with tap water and surface water was gently adsorbed by paper towels. Fig fruits were divided into three batches. In first two batches (3 kg per batch) figs were frozen in syrups [30% (*w/w*) sucrose syrup (SUC) and 30% (*w/w*) sucrose syrup with 2% (*w/w*) ascorbic acid (SUCAA)] and the third batch was the control sample (CON), where figs were frozen without syrup, packaged only in polyethylene (PE) bags (10 figs per bag). The figs in syrups were individually frozen in plastic jars containing previously prepared syrups and jars were packaged in PE bags (six jars per bag). All samples were stored at –18 ^{0}C for 70, 140 and 210 days. For analysis purpose, figs from each batch after each storage period were divided into two series: i) fig were thawed for color, TSS and pH measurement as well as sensory analysis and ii) figs intended for sugars and phenolic analysis by High Performance Liquid Chromatography (HPLC) were freeze–dried. Prior to freezing, fresh figs (day 0) were also analyzed.

For TSS and pH measurement, figs were homogenized with kitchen stick mixer (CNHR9EV, Bosch, Slovenia) and TSS (°Bx) were determined by refractometer (PAL-3, ATAGO, Japan). pH-meter (SevenEasy pH Meter S20, Mettler Toledo, Switzerland) was used for pH determination. All measurements were done in a duplicate.

Color analysis of fruit skin and fruit pulp was done according to CIELAB method by measuring L^* [lightness, (0-100)], a^* [redness (+) to greenness (-)] and b^* [yellowness (+) to blueness (-)] of three fruits of each sample using colorimeter (Spectrophotometer CM-3500d, Konica Minolta, Japan) with 8 mm diameter hole measuring plate and black cylinder cover. Hue angle (h^*) was calculated as arc tan (b^*/a^*).

Sensory evaluation was conducted by 6 panelists chosen from the faculty staff, by using Quantitative Descriptive Analysis (QDA). Before the analysis, panelists were trained in three hours' session where they practiced the regular testing procedure and they participated in defining and modifying (Sortino et al., 2017) sensory descriptors (fig odor, ethanol odor, off-odor, fig taste, sweetness, off-taste, fig flavor, off-flavor, ease of peeling, firmness of the fruit skin, typical skin color, typical pulp color and typical fruit firmness). Descriptors were rated by 5-point scale (Cetinkaya et al., 2006; Dite Hunjek et al., 2020; Martínez-Damián et al., 2020) according to the presence and/or intensity (0 = absent; 5=very pronounced) of certain attribute. Samples were evaluated on the day of analysis and they were served on the porcelain coded plates.

Sugars extracts for HPLC analysis were prepared according to Duarte-Delgado et al. (2015) method with certain modifications. Briefly, freeze-dried samples were homogenized with 80% (*v/v*) methanol by vortex (VELP Scientifica, Usmate, Italy), heated in water bath (60 °C/60 min) and centrifuged (Hettich® Rotofix 32a, Tuttlingen, Germany) at 4427.28 × g/15 min. HPLC analysis was performed with Agilent 1260 Infinity quaternary LC system (Agilent Technologies, Santa Clara, CA, USA) equipped with refractive index detector (RID) using Cosmosil Sugar-D 4.6 IDX250 mm column (Nacalai Tesque, INC., Kyoto, Japan) at temperature of 45 °C with 80% (*v/v*) acetonitrile as a mobile phase.

Phenolic extracts for HPLC analysis were prepared according to the procedure of Slatnar et al. (2011) by acidified methanol with 3% (*v/v*) formic acid in ultrasonic bath (Elmasonic 40H, Elma, Germany) for 30 min at 50 °C and subsequent centrifugation at 3000 × g/10 min. Separation was done on a Nucleosil 100-5C18, 5 mm (250 mm×4.6 mm i.d.) column (Macherey-Nagel) by HPLC (Agilent 1260 Infinity quaternary LC system) equipped with UV/VIS– photodiode array detector. The elution was gradient with two mobile phases: A - 3% formic acid in water (*v/v*); B - 3% formic acid in 80% acetonitrile (*v/v*) (Zorić et al., 2014).

The identification of individual sugars was done by retention times of standards, while the identification of phenolic compounds was based on the characteristic spectra and retention times of standards. Quantification of sugars and phenolics was done by external standard curves and by comparison with the peak areas of authentic standards, respectively. Sugars were expressed as g 100 g^{-1} of fresh weight (fw) and phenolics as mg 100 g^{-1} of fw. All analyses were performed in a duplicate. Results were expressed as average values±standard deviation.

The influence of freezing procedure and storage time was statistically analyzed by analysis of variance (ANOVA) at significant level $p \leq 0.05$.

Results and discussion

Freezing conditions and 210 days' storage at -18 °C had statistical influence on pH, TSS, and total sugars (Table 1).

Table 1. F-value and p-value in the ANOVA analysis of influence of freezing conditions and 210 days' storage of figs

Tablica 1. F-vrijednost i p-vrijednost u analizi varijance utjecaja uvjeta smrzavanja i 210 dana skladištenja pri -18 °C

Parameter/Parametar	Freezing conditions/ Uvjeti smrzavanja		Storage time/ Vrijeme skladištenja	
	F	p	F	p
pH	2347	<0.01*	2304	<0.01*
TSS/TST	33.38	<0.01*	146.56	<0.01*
Total sugars/Ukupni šećeri	1133.1	<0.01*	7588.1	<0.01*
*L** skin/*L** pokožice	3.733	0.04*	5.834	<0.01*
*L** pulp/*L** pulpe	55.80	<0.01*	179.62	<0.01*
Total phenolics/Ukupni fenoli	352.44	<0.01*	112.62	<0.01*
Skin color/Boja pokožice	13.846	<0.01*	78.343	<0.01*
Pulp color/Boja pulpe	9.273	<0.01*	72.721	<0.01*
Ease of peeling/Lakoća guljenja	0.1392	0.87	46.4522	<0.01*
Firmness of the fruit skin/Čvrstoća pokožice	0.1205	0.89	115.1004	<0.01*
Fruit texture/Tekstura ploda	0.392	0.68	106.438	<0.01*
Fig odor/Miris po smokvi	0.5525	0.58	49.5919	<0.01*
Ethanol odor/Miris na alkohol	0.2025	0.82	2.4663	0.07
Off-odor/Strani miris	5.3529	0.01*	16.0719	<0.01*
Fig taste/Okus na smokvu	5.370	0.01*	50.871	<0.01*
Sweetness/Slatkoća	2.852	0.07	20.216	<0.01*
Off-taste/Strani okus	2.7059	0.07	2.9028	0.04*
Fig flavor/Aroma na smokvu	7.833	<0.01*	44.530	<0.01*
Off-flavor/Strana aroma	11.0595	<0.01*	14.9339	<0.01*

TSS: total soluble solids/TST: topljiva suha tvar *p≤0.05

Fresh figs (initial sample) were characterized with very high pH (5.16) and TSS (28.85%) (Table 2) what is higher than most literature data. The figs examined in this study were in full ripe stage, near the over-ripe stage, what could be the reason for such high pH and TSS values. It can also be a specific cultivar feature. Byeon and Lee (2021) reported acidity decrease and TSS increase in figs along with ripening stage, while Sortino et al. (2017) reported different TSS upon fig cultivar (Dottato 17.5% and Melanzana 14.5%). Usberty et al. (2021) and Petkova et al. (2019) also documented different pH values in figs (4.92 and 4.86, respectively). In current study the remarkable lowering of pH and TSS values was recorded during the first 70 days of storage, but after 140 days increase of these parameters (with an exception of pH in SUCAA) was observed in most of the samples. Toward the end of storage these values decreased again. Considering the treatment, the lowest pH and TSS values were measured in SUCAA and the highest ones in SUC. When compared to fresh initial sample, pH and TSS values were lower in all frozen samples. Similarly, Petkova et al. (2019) investigated the influence of four-month storage at –18 °C on fig traits and reported higher moisture and lower pH at the end of storage in comparison with initial fig fruits. During freezing several processes occur in plant tissue such as dehydration of the cells, solute damage and mechanical damage (Reid, 1997), which could contribute to the leakage of solute during thawing, and thus the decrease of TSS. Furthermore, the degradation of pectin (methylated polygalacturonic acid branched with neutral sugars) also occurs during freezing and frozen storage (Van der Sman, 2020), what could possibly have an effect on pH depletion.

Sugars in fresh samples were determined in the decreasing sequence: fructose (11.16 g 100 g^{-1}) > glucose (10.53 g 100 g^{-1}) > sucrose (0.12 g 100 g^{-1}) (Table 2). Similarly, Çalişkan and Polat (2011) examined 72 fig cultivars from Turkey and determined fructose in higher level than glucose, but their content in all cultivars was lower than in the current study. Moreover, sucrose was also determined in negligible quantities and it was not even detected in some cultivars (Çalişkan and Polat, 2011). Remarkable decrease of all sugars was observed in CON and SUC samples only in the first 70 days' period, while during further storage their content increased noticeably. Increasing trend of fructose and glucose level during entire storage time was observed in SUCAA, while after 70th day sucrose was not detected in this sample. The highest values of total sugars were determined in all samples at the end of storage (in increasing sequence: CON (29.22 g 100 g^{-1}) < SUC (30.17 g 100 g^{-1}) < SUCAA (31.90 g 100 g^{-1}) in comparison with initial fig (21.81 g 100 g^{-1}). Activity of fig's enzymes linked with sugars transformation, such as α- and β-amylase (responsible for starch depolymerization) and invertase (responsible for sucrose breakdown into glucose and fructose), is present through the whole fruit development (Sedaghat and Rahemi, 2018) and according to Beyon and Lee (2021) sugars level continues to increase even during 30 days of storage at 0.5 °C.

Table 2. Results of pH, total soluble solids (TSS), individual and total sugars (g 100 g^{-1} fresh weight) determination in examined figs samples

Tablica 2. Rezultati određivanja pH, topljiva suha tvar (TST), pojedinačni i ukupni šećeri (g 100 g^{-1} svježeg uzorka) u ispitivanim uzorcima smokava

Sample/ Uzorak	Days/ Dani	pH	TSS (%)/ TST (%)	Fructose/ Fruktoza	Glucose/ Glukoza	Sucrose/ Saharoza	Total Sugars/ Ukupni šećeri
Fresh/svježi	0	5.16±0.01	28.85±0.64	11.16±0.01	10.53±0.01	0.12±0.02	21.81±0.04
CON	70	4.67±0.03	22.65±0.21	8.57±0.09	8.43±0.08	0.01±0.00	17.00±0.17
	140	4.94±0.01	25.70±0.14	12.94±0.08	12.40±0.05	0.03±0.00	25.36±0.12
	210	4.77±0.02	23.75±0.35	14.81±0.10	14.39±0.10	0.02±0.00	29.22±0.20
SUC	70	4.55±0.01	23.40±1.13	9.09±0.01	8.42±0.08	0.01±0.01	17.53±0.06
	140	4.91±0.01	26.45±0.21	13.99±0.04	13.04±0.01	0.03±0.00	27.05±0.04
	210	4.90±0.01	24.85±0.35	15.12±0.15	15.01±0.03	0.04±0.01	30.13±0.12
SUCAA	70	4.60±0.01	22.30±0.28	11.23±0.00	10.65±0.00	0.01±0.00	21.98±0.01
	140	4.37±0.01	23.40±0.71	16.31±0.02	15.03±0.04	nd	31.37±0.05
	210	4.08±0.01	21.30±0.00	16.00±0.17	15.90±0.23	nd	31.90±0.40

CON: Frozen figs without treatment/Smrznute smokve bez tretmana; SUC: Frozen figs in sucrose solution/Smrznute smokve u otopini saharoze; SUCAA: Frozen figs in sucrose+ascorbic acid solution/Smrznute smokve u otopini saharoze+askorbinske kiseline; n.d.: not detected/ nije detektirano

Results are expressed as mean±SD./Rezultati su izraženi kao srednja vrijednost±SD.

Observed increase of sugars in current study could be a consequence of the complex physical, chemical and biochemical processes which occur during freezing and frozen storage due to activity of present enzymes (although it can be low), cell wall degradation, loss of turgor and many other factors (Van der Sman, 2020). Additionally, it seems that a certain diffusion of sucrose from the sucrose solution into the fig fruit happened since the lowest sugars content was recorded in CON. Also, ascorbic acid could have a positive effect in that process because higher sugar level was determined in SUCAA when compared to SUC. However, an inconsistency between TSS and sugars content in all samples at 210th day as well as in SUCAA at 140th day was observed. This could be the result of different sample preparation method since TSS were measured after thawing where a distinct leakage of juice from longer stored figs was present. On the other hand, individual sugars were determined in freeze-dried samples where no leakage occurred. Frozen storage can lead to more textural alteration (Van der Sman, 2020), and according to the results in current study, it is possible that ascorbic acid could accelerate these changes.

Results of individual phenolics of figs depending on freezing conditions and 210 days' storage at -18 °C is depicted in Table 3. Total phenolics content was significantly influenced by freezing conditions and storage time (Table 1). The phenolic profile of fresh fig was composed of quercetin-3-rutinoside (Q-R), which was the most abundant phenol (8.75 mg 100 g^{-1}), followed by anthocyanin cyanidin-3-glucoside (C-G, 4.11 mg 100 g^{-1}), quercetin-acetylglucoside (Q-aG, 2.45 mg 100 g^{-1}), chlorogenic acid (Cha, 1.87 mg 100 g^{-1}) and quercetin-3-glucoside (Q-G, 1.70 mg 100 g^{-1}). All of them were also identified in frozen samples during storage with an exception of Cha in CON at the 140th and the 210th day.

Table 3. Individual and total phenolics (mg 100 g^{-1} fresh weight) in examined figs samples
Tablica 3. Pojedinačni i ukupni fenoli (mg 100 g^{-1} svježeg uzorka) u ispitivanim uzorcima smokava

Sample/ Uzorak	Days Dani	C-G	Cha	Q-R	Q-G	Q-aG	Total phenolics / Ukupni fenoli
Fresh/svježi	0	4.11±0.13	1.87±0.11	8.75±0.17	1.70±0.13	2.45±0.16	18.89±0.69
CON	70	1.77±0.07	1.20±0.10	6.47±0.25	1.37±0.07	2.12±0.14	12.92±0.63
	140	1.87±0.10	0.00±0.00	5.96±0.16	1.82±0.13	3.18±0.20	12.83±0.59
	210	2.26±0.13	0.00±0.00	4.66±0.24	1.11±0.13	1.40±0.08	9.43±0.57
SUC	70	2.18±0.14	0.96±0.03	5.79±0.13	1.45±0.12	2.00±0.11	12.38±0.53
	140	2.71±0.13	1.58±0.07	10.88±0.10	2.04±0.11	2.81±0.13	20.03±0.54
	210	4.44±0.14	1.76±0.04	17.94±0.30	3.15±0.10	3.92±0.16	31.20±0.74
SUCAA	70	4.05±0.11	1.82±0.11	8.27±0.10	1.79±0.11	2.74±0.11	18.67±0.54
	140	2.66±0.03	2.05±0.13	11.78±0.18	2.03±0.05	3.24±0.17	21.75±0.56
	210	3.58±0.06	2.12±0.08	11.50±0.14	2.19±0.06	3.02±0.12	22.41±0.47

CON: Frozen figs without treatment/Smrznute smokve bez tretmana; SUC: Frozen figs in sucrose solution/Smrznute smokve u otopini saharoze; SUCAA: Frozen figs in sucrose+ascorbic acid solution/Smrznute smokve u otopini saharoze+askorbinske kiseline; Q-R: quercetin-3-rutinoside/kvercetin-3-rutinozid; C-G: cyanidin-3-glucoside/cijanidin-3-glukozid; Q-aG: quercetin-acetylglucoside/kvercetin-acetilglukozid; Cha: chlorogenic acid/klorogenska kiselina; Q-G: quercetin-3-glucoside/kvercetin-3-glukozid;
Results are expressed as mean±SD./Rezultati su izraženi kao srednja vrijednost±SD.

Many authors reported its presence in figs among other phenolics (Veberic et al., 2008; Slatnar et al., 2011; Mawa et al., 2013; Russo et al., 2014; Wojdilo et al., 2016; Pereira et al., 2017; Palmeira et al., 2019) and agreed that Q-R is predominant phenolic compound in figs. Quantitative results in current study are in similar range as in mentioned studies. During storage, all phenolics were determined in higher content in SUC and SUCAA in comparison with CON, and their content was higher at the end of storage than in the fresh fig. Most of phenolics showed the decrease at the 70th day in all samples, but during further storage they increased again. This increasing trend was continuous in SUC and SUCAA till the end of storage. On the other hand, this was not the case for all phenolics in CON. Such behavior could be the result of the physiological adaptations of living tissue which include synthesis of antioxidants since the constituents of cells in frozen tissue are exposed to oxidation processes. Cell damage and freeze concentration occur in frozen tissue with ice formation, what provides a better contact of oxidative membrane-bound enzymes and substrate in vacuole (Van der Sman, 2020). It seems that sugar solution applied in current study contributed to such physiological adaptations. According to findings of several authors, phenolic compounds also increased during frozen storage of fruits (Veberic at al., 2014), while some authors reported its reduction (Oszmiański et al., 2009; Pedisić et al., 2019).

Obtained values for skin color (Table 4) are in accordance with literature (Çalişkan et al., 2011; Mahmoudi et al., 2018). Skin brightness (*L**) of the frozen figs was significantly influenced by both sources of variation. It was more pronounced in SUC and SUCAA in comparison with

CON with the highest measured values at the 70th day. Later, L^* slightly decreased but it was still higher for figs in SUC and SUCAA than in CON and fresh sample. Value of h^* represents an angle which defines the color tone and position of color on the CIELAB color wheel. According to the obtained results, h^* of all samples was near 90° (meaning yellow area) with increasing trend during storage of all samples.

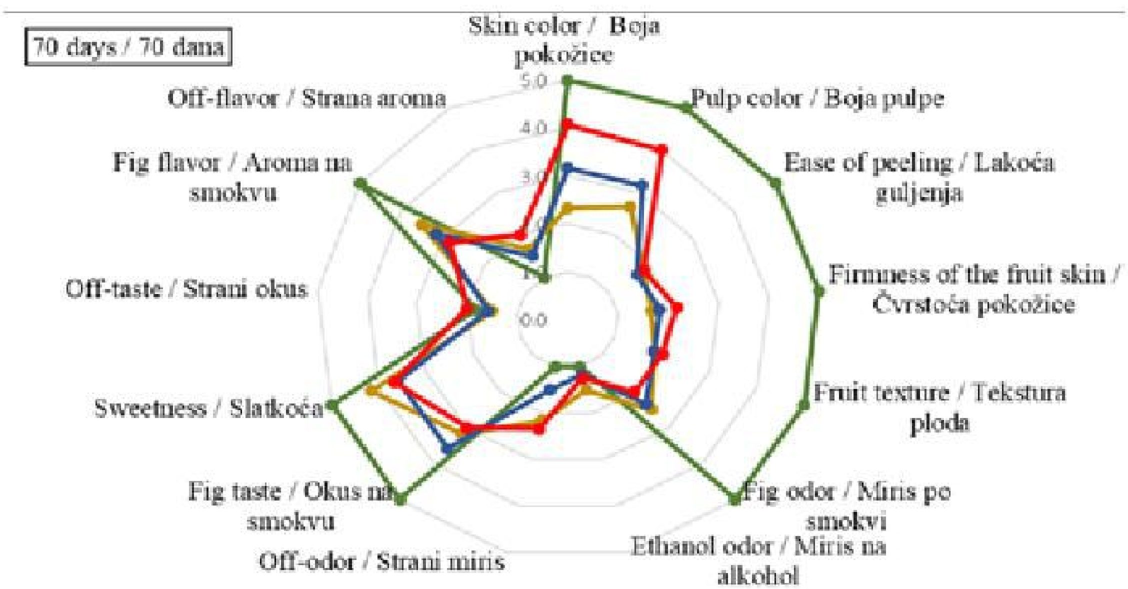
Table 4. Color parameters of examined figs'samples
Tablica 4. Parametri boje ispitivanih uzoraka smokava

Samples/ Uzorci	Days Dani	Skin color/ Boja pokožice		Pulp color/ Boja pulpe	
		L^*	h^*	L^*	h^*
Fresh/Svježe	0	39.37±1.01	79.76±0.31	20.60±0.68	35.96±0.57
CON	70	41.86±1.23	80.29±0.12	20.05±3.80	37.94±0.25
	140	42.17±8.27	75.60±1.28	31.23±0.05	44.50±0.02
	210	42.18±6.62	82.65±1.96	31.97±0.03	54.55±0.12
SUC	70	49.56±5.26	81.31±1.34	19.10±0.00	30.98±0.01
	140	46.62±3.48	82.11±2.09	22.43±0.16	44.66±0.47
	210	43.11±4.25	83.97±2.49	30.99±0.07	59.81±0.09
SUCAA	70	49.54±2.69	82.16±2.00	29.02±0.61	49.71±0.65
	140	47.78±2.10	85.43±1.67	29.05±1.22	35.11±0.92
	210	46.51±3.94	85.48±1.55	35.42±0.03	43.84±0.14

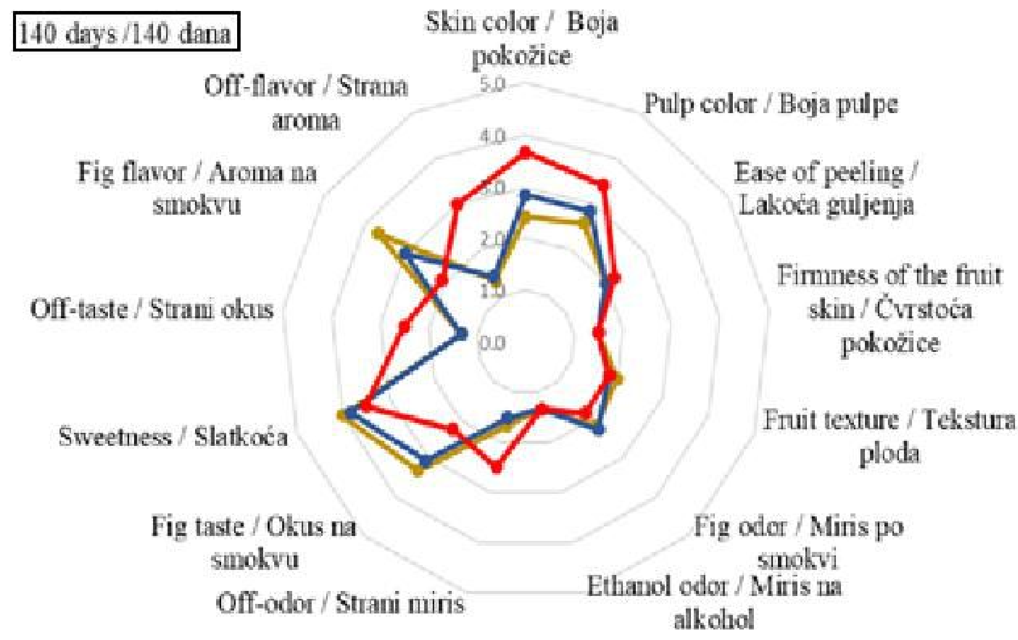
CON: Frozen figs without treatment/Smrznute smokve bez tretmana; SUC: Frozen figs in sucrose solution/Smrznute smokve u otopini saharoze; SUCAA: Frozen figs in sucrose+ascorbic acid solution/Smrznute smokve u otopini saharoze+askorbinske kiseline; n.d.: not detected/ nije detektirano

Results are expressed as mean±SD./Rezultati su izraženi kao srednja vrijednost±SD.

a)



b)



c)

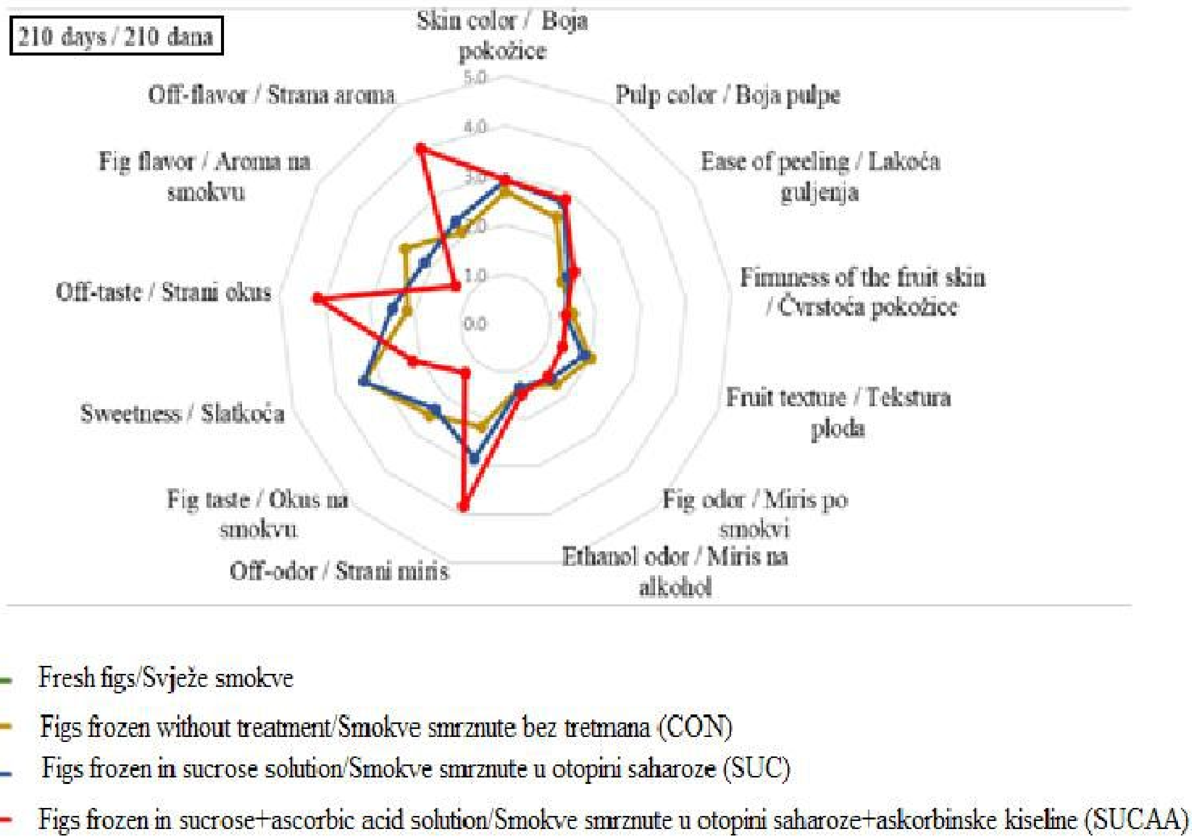


Figure 1. Sensory properties of fresh figs and figs after 70 days of storage (a), figs after 140 days of storage (b) and figs after 210 days of storage (c)

Slika 1. Senzorska svojstva svježih smokava i smokava nakon 70 dana skladištenja (a), smokava nakon 140 dana skladištenja (b) i smokava nakon 210 dana skladištenja (c)

The highest h^* values were in SUCAA and the lowest in CON. L^* value of pulp was significantly influenced by both sources of variation and the highest value was measured in SUCAA at the end of storage. Generally, increasing trend of L^* and h^* during storage was observed, i.e., pulp became brighter and less red. Reduction of red color in frozen blackberry was already reported (Veberic et al., 2014). At the end of storage, SUCAA was the brightest and the reddest sample. Ascorbic acid is known anti-browning agent and it probably contributed to the increased brightness. Moreover, SUCAA had the lowest pH, what probably has a protective effect on anthocyanins which are responsible for red color of fig pulp.

Results of sensory properties of figs depending on freezing conditions and 210 days' storage at -18 °C are shown in Figure 1. Freezing conditions had a significant effect only on off-odor, fig taste, fig flavor and off-flavor, while storage time significantly influenced all sensory attributes except ethanol odor (Table 1). Already during the first 70 days a remarkable decrease of authentic fig attributes was noticed in all samples, but the difference between most of the attributes among samples was not remarkable. Less changes occurred between the 70th and the 140th day, while greater deterioration, especially of fig taste and sweetness was pronounced during the last storage period. At the end of storage, off-odor, off-taste and off-flavor were highly pronounced in SUCAA. Other attributes were also poorly evaluated, what could be partially linked to the greatest observed reduction of TSS and pH. Contrary, it is obvious that SUCAA was the most successful in preserving color, similarly to measured color parameters, but this advantage was not sensorially so noticeable after the 140th day. CON and SUC were very similarly evaluated, but CON had better preserve fig flavor and less pronounced off-odor in comparison with SUC.

Conclusion

Results of current study showed that generally figs are not very suitable for freezing, particularly not for storage longer than 140th days at -18 °C. Further, freezing in 30% sucrose solution did not enhance their quality and sensory properties during frozen storage, especially 30% sucrose solution with the 2% L-ascorbic acid. Conventionally frozen figs retained the best-preserved sensory attributes, although phenolics and sugars were more retained in figs frozen in sugar syrup.

Acknowledgments

This work was funded by University of Zagreb.

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Prispjelo/Received: 30.3.2021. Prihvaćeno/Accepted: 19.4.2021.

Izvorni znanstveni rad

Smrzavanje smokve u šećernim otopinama: kvaliteta, fenolni sastav i senzorska svojstva tijekom skladištenja

Sažetak

U radu se pratio utjecaj smrzavanja u otopini šećera na kvalitetu, fenolni sastav i senzorska svojstva smokava tijekom skladištenja. Svježe smokve zamrznute su bez tretmana (kontrola - CON), u otopini saharoze (30%) (SUC) te otopini saharoze (30%) s askorbinskom kiselinom (2%) (SUCAA) te su čuvane pri -18 °C 210 dana. Svakih sedamdeset dana u uzorcima je određivan pH, topljiva suha tvar (TST), sastav šećera i fenola, boja pokožice i pulpe te se provodilo senzorsko ocjenjivanje. Analiza podataka (ANOVA) je pokazala da vrijeme skladištenja ima značajan utjecaj na više parametara u usporedbi s uvjetima smrzavanja. CON i SUC uzorci imali su najviši TST, što se odrazilo na višu senzorsku ocjenu. SUCAA uzorak bio je senzorski ocijenjen s najnižom ocjenom za slatkoću i tipičan okus smokve te s najvišom ocjenom stranog okusa, arome i mirisa. Suprotno TST-u, pojedinačni šećeri i fenoli bili su najniži u CON. Najsvjetlija boja pokožice i najveći udio crvene boje u pulpi izmjereni su kolorimetrom za SUCAA, a tom uzorku je i senzorski boja pokožice i pulpe najbolje ocjenjena. Tijekom skladištenja TST i pH su se smanjivali, što se odrazilo na senzorski lošije ocjenjenu aromu i okus na smokvu, kao i pojavu stranog okusa, arome i mirisa u svim uzorcima. Suprotno tome, pojedinačni šećeri i fenoli pokazali su porast tijekom skladištenja, iako su u najnižoj koncentraciji određeni u CON. Zaključno, nakon 140 dana zamjetno su poželjna senzorska svojstva smokava sve manje izražena, pri čemu je CON najbolje ocijenjen, a SUCAA najlošije.

Ključne riječi: *smrzavanje smokve, otopina saharoze, kvaliteta, senzorska svojstva, skladištenje*