AcademicPres

Available online at www.notulaebotanicae.ro

Print ISSN 0255-965X; Electronic ISSN 1842-4309

Not. Bot. Hort. Agrobot. Cluj 37 (2) 2009, 200-205

Notulae Botanicae Horti Agrobotanici Cluj-Napoca

The Influence of Postharvest Storage on Quality Characteristics of Fruit of Eggplant Cultivars

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Abstract

Quality changes of eggplant (*Solanum melongena* L.) fruits, as affected by short-term storage at simulated retail conditions were investigated. The fruits were obtained from greenhouse-grown plants. The cultivars chosen for the experiment were: 'Scorpio', 'Oscar', 'Tango' and DRA 2086. The fruits were harvested in the middle of June, at marketable maturity, wrapped with stretch film and stored for one week at 16°C temperature. Before and after storage there were determined: fruit firmness, puncture load of flesh, colour of skin with CIE L*a*b* system, soluble solids content, total phenolics content in fruit flesh and skin, free phenolic acids in flesh and skin (with HPLC method). Sensory quality of the fruits was determined with quantitative descriptive analysis in expert panel, using 19 quality attributes. Results of the experiment showed that both the storage and the genotype affected several quality attributes of the fruits concerning physical characteristics and chemical composition, which can be perceived by instrumental and sensory methods. Flesh firmness and flesh puncture load decreased, as well as soluble solids content. Total phenolics content in fruit skin increased during storage, but the content in flesh was not affected. From free phenolic acids, chlorogenic acid was found in the highest amount, and its content in fruits decreased during storage.

Keywords: aubergine, cultivars, chemical composition, sensory quality, storage, shelf-life

Introduction

Eggplant (*Solanum melongena* L.) fruits are harvested at the physiologically non-mature stage. In fresh weight they contain about 7% of dry matter, 1% of proteins, and 4% of carbohydrates (Esteban *et al.*, 1992). Also vitamins B1, B2, B6 and C were found in the fruits. Consumption of eggplant fruits can decrease LDL level in human blood due to hypolipidemic effect of flavonoids and improve heart action (Sudheesh *et al.*, 1997; Kashyap *et al.*, 2003). Extracts from eggplant fruit have demonstrated high capacity in scavenging of superoxide free radicals and inhibition of hydroxyl radical generation (Noda *et al.*, 2000).

Eggplant fruits are rich in phenolic compounds (Hanson *et al.*, 2006). Phenolics show high biological activity (Lattanzio, 1987; Babic *et al.*, 1993; Leja *et al.*, 1997). They have antioxidant, antibacterial and immunostimulant properties. Phenolic acids are components of lignins and tannins, and also occur as esters or glycosides (Macheix *et al.*, 1990). Phenolic compound nasunin, an anthocyanin, was isolated from the skin of purple-skin eggplant fruit (Noda *et al.*, 2000). Stommel and Whitaker (2003) distinguished about 14 phenolic compounds in eggplant collection.

According to Gajewski *et al.* (2007), fruits of various eggplant genotypes differed in respect of several sensory attributes. Maturity stage of the fruits also affected their sensory quality (Gajewski and Arasimowicz, 2004). Firmness of eggplant fruits and sugars content are important quality parameters, which influence sensory quality of the fruits (Jha and Matsuoka, 2002). Gajewski (2002a, 2002b) reported that during storage firmness of eggplant fruits and the total sugars content decreased. Esteban *et al.* (1992) found that during development of fruits, the titratable acidity, reduced and total sugars, ascorbic acid, proteins and the total phenolics content increase. Eggplant fruits are chilling sensitive at temperatures below 10°C. At 5°C, chilling injury will occur in 6-8 days (Concello *et al.*, 2007). Therefore, for storage temperature above 10°C is recommended (Cantwell and Suslow, 2009).

The objective of this study was to examine the influence of storage in simulated retail conditions, on quality indices of fruits of greenhouse-grown eggplant cultivars, including sensory quality, firmness, skin colour, phenolics and soluble solids content.

Materials and methods

Material

The experiment was carried out at Warsaw University of Life Sciences. The four eggplant cultivars chosen for the experiment were: 'Scorpio', 'Oscar', 'Tango' and DRA 2086 (De Ruiter Seeds). Fruits of 'Scorpio', 'Oscar' and DRA 2086 are typical for cultivars of violet-black type, and fruits of 'Tango' have plain creamy-white skin. Eggplants were planted to the greenhouse in the middle of April. Modern greenhouse with fertigation system was used in the experiment. Nutrients concentration, EC and pH were kept at recommended level. During fruits development the temperature ranged from 20-to 25°C during the day and between 18-20°C during the night. Fruits were harvested in the middle of June, at marketable maturity. After harvest, the fruits were wrapped with PE stretch film and stored for one week at 16oC, which simulated retail conditions ('shelf-life').

Instrumental analysis

Fruit flesh firmness was measured with Fruit Firmness Tester HPE II (Bareiss, Germany), equipped with a 5 mm diameter, round-ended probe, according to the method used by Huyskens-Keil *et al.* (2006). Firmness was measured in the range of 0–100, where the value 100 was the measured data from a standardized metal disc. The measurement for each fruit was carried out on four equidistant records. The average value was computed on 10 fruits per combination and was expressed in HPE values.

The force needed to puncture the fruit flesh without skin ('puncture load') was determined by hand penetrometer (David Bishop Instruments), using a 10 mm diameter probe. The measurement for each fruit was carried out on four equidistant points. The average force value was computed on 4 fruits per combination and expressed in Newtons (N).

Skin colour of the fruits was measured with Hunter-Lab XE colorimeter, and the parameters were expressed in CIE L*a*b* system, where L* is lightness (ranged from 0 to 100 units), a* is light intensity in red (+) or green (–) spectrum, b* is intensity in yellow (+) or blue (–) spectrum.

Dry matter was determined by drying samples at 105°C until obtaining stable weight. Soluble solids content in raw and roasted fruits was determined with a digital Abbe's refractometer. The measurements were done on representative samples from four fruits and expressed in ºBx.

Total phenolic compounds content was determined with standard Fiolin-Ciocialteu method. Free phenolic acids in fruit flesh and skin were separated with HPLC method. 5.0 g of grounded material was extracted with methanol in Büchi B-811 Extraction System. After evaporation of solvent, the residue was dissolved in methanol, filtered and subjected to HPLC. Shimadzu chromatograph was used, with SPD-M10A VP DAD detector, equipped with Luna 5 µm C18 (2) 250 mm x 4.6 mm column. The gradient of 10% ACN (A) and 55% ACN (B) was used as follows: 0 min, 15% B; 30 min, 75% B; 31.01 min, 100% B; 35 min, 100% B; 35.01 min 15% B. The following pa-

Tab.1. Definitions of sensory attributes used in the quantitative descriptive analysis

No.	Attribute	Definition	Anchoring points
1	Overall odour intensity	General impression of odour intensity	Undetectable – very intensive
2	Sharp odour	Pungent, spicy odour	Undetectable – very intensive
3	Odour of 'steamed potatoes'	Characteristic odour of steamed potatoes	Undetectable – very intensive
4	Odour of 'boiled fungi'	Characteristic odour for boiled fresh fungi	Undetectable – very intensive
5	Sour odour	Odour of sour character	Undetectable – very intensive
6	Odour of 'hay'	Odour characteristic to long stored hay	Undetectable – very intensive
7	Odour of 'plum jam'	Sweety odour, characteristic to plum jam	Undetectable – very intensive
8	Off-odour	Unusual odour for eggplant fruit	Undetectable – very intensive
9	Flesh colour	Visual evaluation of flesh colour	Light – dark brown
10	Flesh firmness	Degree of force needed to chew the flesh	Firm - soft
11	Flesh fibrousness	Mouthfeel of flesh homogenousness	Smooth – very fibrous
12	Skin hardness	Degree of force needed to bite the skin	Hard – soft
13	Sweet taste	Basic taste	Undetectable – very intensive
14	Flavour of 'boiled fungi'	Characteristic flavour of boiled fresh fungi	Undetectable – very intensive
15	Flavour of 'roasted fruit'	Characteristic flavour of roasted apples	Undetectable – very intensive
16	Sour taste	Basic taste	Undetectable – very intensive
17	Bitter taste	Basic taste	Undetectable – very intensive
18	Pungent flavour	Impression of burning on tongue	Undetectable – very intensive
19	Off-flavour	Unusual flavour for eggplant fruit	Undetectable – very intensive
20	Overall quality	Score for general sensory impression	Low – high quality

rameters were applied: flow rate 1.0 ml ·min^{-1}, oven temperature 36°C, time of analysis 40 min.

Sensory analysis

Sensory evaluation of the fruits was performed according to the ISO standards (Anonymous 1996, 1998) in sensory laboratory, in expert panel consisting of 12 assessors. For the evaluation the quantitative descriptive analysis (QDA) was applied. At the first part of QDA procedure 'brainstorming' sessions were run to select attributes for the fruits. The set of 19 quality attributes and overall sensory quality were evaluated (Tab. 1). For the assessments fruits were roasted in PE bags for 60 minutes at the temperature of 180°C, and then cooled to ambient temperature. Samples of the fruits (slices, 1 cm thickness) were put to coded plastic boxes, covered with lids, and served to the assessors. Every assessor was given randomized samples. The assessments for each descriptor were marked on non-structural lines, with anchoring points (low intensity – high intensity of impression). Results were converted to numerical values (from 0 to 10). The analysis was performed in two independent sessions.

Data elaboration

For the variance analysis 'Statgraphics Plus 4.1' software was applied, and Tukey's HSD test was used to determine which mean differ significantly at the P=0.05probability level

Results and discussion

According to literature, eggplant fruits are characterized by poor storage ability. They can be stored keeping their good quality and without the risk of chilling injury for two weeks only, 10–12 ^{0}C (Concello *et al.*, 2007; Cantwell and Suslow, 2009). However, in retail conditions with higher temperatures, shorter durability of the fruits and an accelerated quality deterioration can be expected. At our experiment eggplant fruits were kept wrapped in PE film at temperature simulating the shelf-life of the product. Results of the experiment showed that the short-term storage in those conditions significantly affected some of the quality attributes of the fruits, concerning physical, chemical and sensory traits. Data for the physical attributes, concerning colour and texture of the fruits, are presented in Tab. 2. The colour parameters, expressed in CIE L*a*b* system, were not significantly affected by the storage, but had been different between the cultivars. Firmness of the fruits, expressed in oHPE scale, decreased significantly during storage. From the four cultivars, DRA 2086 fruits were the most firm. Flesh puncture load decreased during storage as well, but differences between the cultivars were insignificant in that case.

The influence of the storage regarding chemical composition of the fruits, in respect of dry matter, total phenolics and soluble solids contents is shown in Tab. 3. Dry matter of the fruits decreased significantly (from about 6.1% to about 5.8%). It could be a result of sugars loss in respiration process, which occurs in stored produce, as it is widely described in literature. Significant changes of sugars content in eggplant fruits were also observed during storage at optimal temperature (Gajewski, 2002b). Respiration process can result in soluble solids decreasing in the fruits. We found a tendency to lower the soluble solids content in the stored fruits than in the freshly harvested ones, but in the raw material only. Roasted fruits showed similar soluble solids content at both terms of evaluation.

According to literature, eggplant fruits are rich in phenolic compounds (Hanson *et al.*, 2006). We found that the content of total phenolic compounds in fruit flesh reached the level of 0.75-1.25 mg g^{-1} fw, and in the skin of the fruit it was about 3-times higher (except 'Tango', which showed a generally low phenolics content in the skin). These values are generally in accordance with the data reported by Hanson *et al.* (2006). In their report, means for total phenolics content, averaged over years, ranged from 0.74 to 1.43 g 100^{-1} g dw. In our study, storage of the fruits was not significantly affected the total phenolics content in fruit flesh, but resulted in about 50% increasing of their content in fruit skin, except 'Tango'. According to Stommel and Whitaker (2003), a big part of phenolic compounds consists of anthocyanins. 'Tango' was the only one cultivar of the four, characterized by a white skin (not containing blue pigments - anthocyanins), therefore low content of phenolics in its skin, before and after storage period, was expected. Free phenolic acids are another important part of plant phenolics. From them, chlorogenic acid, 3-4-dihydroxycinnamic acid and rosmarinic acid were detected in

Tab. 2. Physical traits of eggplant fruit in relation to term of evaluation and cultivar

Means for factors		Skin colour in CIE system			Flesh firmness (°HPE)	Flesh puncture load (N)
		L*	a*	b*		
Terms	freshly harvested	40.1 a	0.9 a	2.9 a	42.9 b	7.6 b
	after storage	40.1 a	1.0 a	2.6 a	35.9 a	6.8 a
Cultivars	Scorpio	23.6 a	1.5 b	-0.1 a	38.7 a	7.0 a
	Oscar	23.9 a	1.7 b	0.1 a	38.5 a	6.9 a
	Tango	89.2 b	–1.2 a	11.4 b	37.0 a	6.9 a
	DRA2086	23.8 a	1.8 b	-0.2 a	43.4 b	7.9 a

Note: means for factors which do not differ according to Tukey HSD test at P=0.05 are marked with the same letters

Tab. 3. Chemical composition of fruit flesh in relation to term of evaluation and cultivar

Means for factors		Dry matter (%)	Total phenolics (mg g^{-1} fw)		Soluble solids (°Bx)	
			in flesh	in skin	Raw	Roasted
Terms	freshly harvested	6.13 b	0.92 a	2.11 a	5.2 a	3.8 a
	after storage	5.83 a	0.99 a	3.16 b	5.0 a	3.9 a
Cultivars	Scorpio	6.10 b	0.83 a	3.20 b	5.1 ab	3.6 a
	Oscar	6.15 b	0.98 a	2.76 b	5.3 b	4.2 b
	Tango	5.62 a	0.99 a	0.83 a	4.9 a	3.5 a
	DRA2086	6.06 b	1.03 a	3.75 b	5.2 b	4.1 b

Note: see Tab. 2.

Tab. 4. Free phenolic acids in flesh in relation to term of evaluation and cultivar (mg 100 g^{-1} dm)

Means for factors		Free phenolic acids			Total free phenolic acids
		Chlorogenic acid	3-4-dihydroxycinnamic acid	Rosmarinic acid	
Terms	freshly harvested	212.6 b	1.0 a	1.2 a	214.9 a
	after storage	134.2 a	1.4 a	1.2 a	142.5 a
Cultivars	Scorpio	154.4 a	1.0 a	1.5 a	159.4 a
	Oscar	159.5 a	1.5 a	1.0 a	166.0 a
	Tango	223.9 b	1.5 a	1.2 a	228.5 b
	DRA2086	155.8 a	0.9 a	0.9 a	160.7 a

Note: see Tab. 2.

eggplant fruit flesh (Tab. 4). The most abundant acid was chlorogenic acid, amounted for above 97% of the three acids. After storage, the amount of chlorogenic acid in the flesh decreased markedly. It was also found that fruits of 'Tango' were the richest in phenolic acids, but only freshly harvested. Eggplant fruit skin was rich in chlorogenic acid (except 'Tango'), but also rosmarinic acid was presented in a quite high amount in 'Scorpio' and 'Oscar' fruits skin (Tab. 5). However, the amount of chlorogenic acid in fruit skin decreased dramatically after storage.

QDA results for eggplant fruits in relation to storage period, are shown in Fig. 1-4 in the form of profiles, for each cultivar separately. For QDA data presentation, such profiles are usually used in literature (Chabanet, 2000). It can be seen that the profiles differ between the cultivars in respect of most attributes, for 'Tango' fruits especially. Differences in sensory quality between other cultivars from plastic tunnel cultures were reported (Gajewski and Arasimowicz, 2004). Storage of the fruits resulted in changes of their quality characteristics, and most of these changes were similar for all cultivars. For 'Scorpio' fruits, the changes were found for : odour of 'steamed potatoes' and odour of 'boiled fungi', flesh firmness, sweet taste and pungent flavour (Fig. 1). After storage period ,firmness and sweet taste of the fruits decreased and pungent flavour intensity increased. In the case of 'Oscar' fruits there can be seen differences in odour attributes, namely in sharp odour, odour of 'steamed potatoes', of 'boiled fungi' and 'hay' odour, which were scored on significantly lower level after storage of the fruits (Fig 2). Also flesh firmness and some flavour attributes, namely sweet taste, flavour of 'roasted fruits' were affected by storage. Fruits obtained from 'Tango' cultivar showed similar changes after storage as fruits obtained from 'Oscar', except flesh firmness, which was not affected by the storage (Fig. 3). Initial firmness of 'Tango' fruits was rated higher than firmness of the fruits from other cultivars, however. The biggest differences in sensory quality in relation to storage can be seen in the

Tab. 5. Free phenolic acids in fruit skin in relation to term of evaluation and cultivar (mg 100 g^{-1} dm)

Means for factors		Free phenolic acids			Total free phenolic acids
		Chlorogenic acid	3-4-dihydroxycinnamic acid	Rosmarinic acid	
Terms	freshly harvested	234.1 b	3.5 a	14.5 b	279.1 b
	after storage	75.8 a	6.1 b	6.8 a	109.4 a
Cultivars	Scorpio	224.9 b	6.8 b	19.1 b	287.5 b
	Oscar	183.0 b	7.4 b	15.8 b	235.8 b
	Tango	81.2 a	3.1 a	3.1 a	101.0 a
	DRA2086	130.9 a	1.9 a	4.6 a	152.7 a

Note: see Tab. 2.

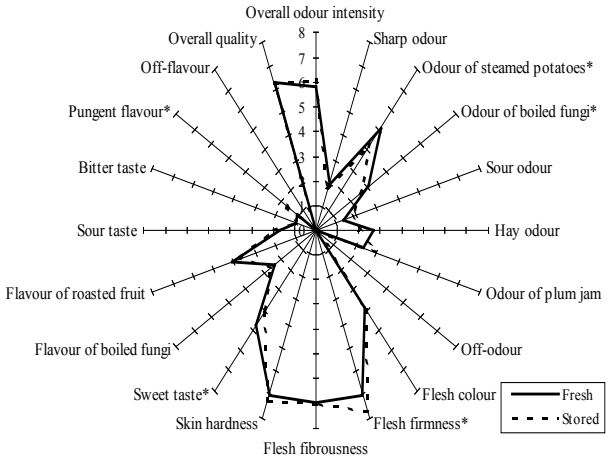

Fig.1. Sensory quality profiles for 'Scorpio' fruits.

Note: significant difference at P = 0.05 between samples, in respect of given attribute, is marked with asterisk.

case of DRA 2086 fruits (Fig. 4). Texture attributes – flesh firmness, fibrousness and skin hardness – were especially affected. Skin hardness is an important quality trait when the fruit is eaten as a whole, with the skin. Also sweet taste was significantly lower scored in stored fruits.

When we compare the results of the instrumental measurement of firmness, presented in Tab. 2, with the results of the sensory evaluation, similar relationship between the data from the both terms of evaluation can be noticed. It should be mentioned, that sensory evaluation was performed on roasted fruits, in opposite to instrumental measurement of firmness.

Bitter taste, which is characteristic taste for eggplant

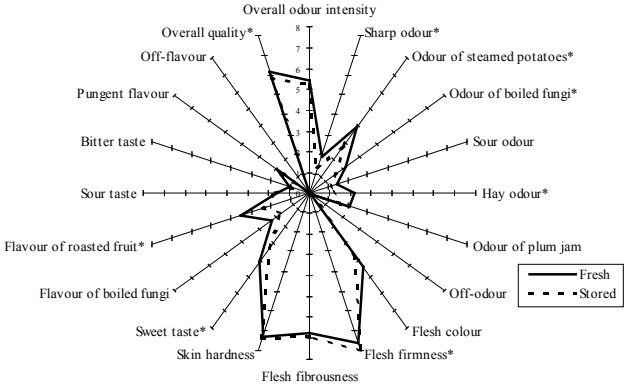

Fig. 2. Sensory quality profiles for 'Oscar' fruits.

Note: see Fig. 1.

fruits, but not desirable in a higher amount, was rated on a very low level for all fruits, and it was insignificantly affected by the storage. Bitter taste of eggplant fruit may result from alcaloids and polyphenolic acids presence in the fruits (Hanson *et al.*, 2006). Fruits rich in these compounds can be rated as more bitter. Humans are born with an innate dislike for bitter taste and with preference for sweet one. Generally, sweet taste of a fruit is an effect of sugars presence in the flesh. In respect of fruit flesh colour impression, this attribute was affected by storage in the case of 'Oscar' and DRA 2086 fruits. The darkest flesh was typical for freshly harvested fruits of DRA 2086, but after storage the flesh was rated as slightly paler.

Overall quality score is based on scores for all sensory quality attributes and summarize quality impression of the evaluated sample. In the case of 'Oscar', 'Tango' and DRA 2086, overall quality of the fruits was scored on significantly lower level after storage than immediately after

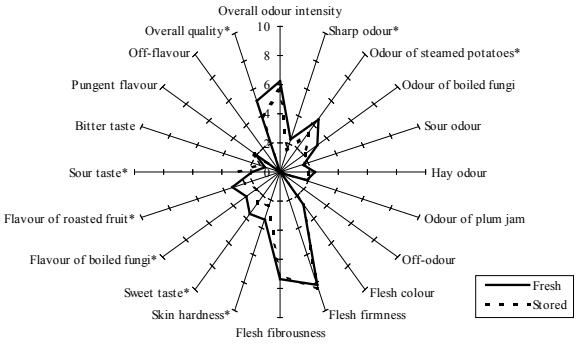

Fig. 3. Sensory quality profiles for 'Tango' fruits.

Note: see Fig. 1.

harvest. Among other changes, storage of the fruits resulted in decreasing flesh firmness and sweet taste intensity. Regardless of a cultivar and term of evaluation, the fruits did not show any noticeable amount of off-flavour, which is generally thought as an undesirable trait. It can be seen on the profiles that from the four cultivars fruits of 'Scorpio' showed the smallest quality changes during storage in respect of odour and flavour attributes.

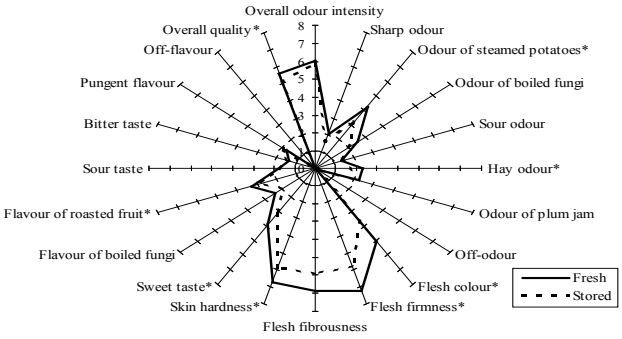

Fig. 4. Sensory quality profiles for DRA 2086 fruits.

Note: see Fig. 1.

Conclusions

Short-term storage of eggplant fruits at simulated retail conditions affected several quality attributes of the fruits, concerning their physical characteristics and chemical composition, which can be perceived by instrumental and sensory evaluation methods.

Flesh firmness and puncture load of the fruits decreased during fruit storage, which affected sensory attributes related to texture of the fruits.

Dry matter content in the fruits decreased during storage, but changes in soluble solids content showed no clear tendency.

Total phenolic compounds content in fruit skin increased during storage, but the content in fruit flesh was not affected.

Chlorogenic acid was the dominating phenolic acid from those detected in the fruits and its amount in fruit flesh and skin decreased during storage.

Storage influenced taste / flavour attributes of the fruits, including intensity of sweet taste and intensity of some characteristic flavours, e.g. flavour of 'roasted fruits' and flavour of 'boiled fungi', which decreased markedly.

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