



PRE- AND POSTHARVEST NUTRITIONAL VALUE AND STORAGE ABILITY OF SCALLOP SQUASH CULTIVARS

Agnieszka BALBIERZ*, Eugeniusz KOŁOTA

Wrocław University of Environmental and Life Sciences,

The Faculty of Life Sciences and Technology, pl. Grunwaldzki 24A, 53-363 Wrocław, Poland

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ABSTRACT

Scallop squash fruit may be harvested and supplied to the fresh market at different stages of maturity. However, small size and immature fruit, preferred by the consumers and food industry, have only a limited storage life, which duration, among others, depends on cultivar characteristic. The objective of the study was to evaluate the storage ability and pre- and postharvest nutritional value of small size fruit of 'Disco', 'Polo F₁', 'Sunny Delight F₁', 'Gagat' and 'Okra' scallop squash cultivars. Fruit with diameter 3-6 cm, harvested at the time of maximum fruiting, were placed in the storage room with temperature 7 °C, and relative humidity > 95% for the period of 1 or 2 weeks. Results of the study showed that prolonged up to 14 days period of fruit storage caused a drastic, within 9.95% – 13.95% weight loss, which was associated with visual symptoms of wilting and significant decrease of dry matter, sugars, vitamin C, carotenoids and nitrates contents. Among examined cultivars, the best suitable for the short storage, lasted no longer than 7 days, appeared to be 'Disco' and 'Okra'. 'Sunny Delight F₁', the only one cultivar with yellow color of skin, containing high amounts of vitamin C and polyphenols and showing low tendency to nitrates accumulation, similarly as 'Gagat' and 'Polo F₁', were less suitable for short period of cold storage.

Key words: storage period, weight losses, sugars, antioxidants, nitrates

INTRODUCTION

Scallop squash (*Cucurbita pepo* L. var *patisonina* Greb f. *radiata* Nois.), belonging to the group of bush type summer squashes, can be consumed at different stages of fruit development. Those picked up in advanced phases of development or in full maturity, when receive the diameter about 20 cm, and weight 1.5-2.0 kg, can be directly supplied to the fresh market or after cold storage. In temperature within 5-10 °C and relative air humidity around 95% they can be stored for the period of 2-3 months (Desai & Masmade 1998; Gajewski & Grzeszczuk 2005).

Small size fruits with diameter 3-6 cm, harvested at the time before the skin begins to harden and does not need to remove it, are preferred by the consumers to use for boiling or pickling, as well as by the food industry for canning, freezing or dehydration

(McCollum 1992; Gajewski & Grzeszczuk 2005). The other valuable feature of such fruit is their high nutritional value expressed by such health promoting compounds as vitamins, minerals and antioxidants. Studies conducted by Gajc-Wolska and Skąpski (1994), and Grzeszczuk and Falkowski (2002, 2003) indicated that small size fruit of scallop squash contained higher amounts of vitamin C, dry matter, macro- and micronutrients if compared to those harvested at later stages of development. However, such immature fruit have a limited storage life, usually not longer than 1 or 2 weeks, depending, among others, on the cultivar. As it was reported by Gajewski (1995), small size fruit of scallop squash, similarly as zucchini, are sensitive to temperature below 6 °C, and its drop to 3 °C causes chilling injury, which occurs by the pitting of fruit surface. As the optimum conditions for soft-

*Corresponding author:
e-mail: a.balbierz@o2.pl

rinds summer squashes fruit is considered 7-10 °C and relative humidity 85-95% (Thompson 2002).

Actually in Polish Register List of Vegetable Crops there are 5 cultivars of scallop squash diversified in terms of their shape and color of fruit, as well as nutritional value. The aim of the study was to evaluate the storage ability of these cultivars, when harvested at the stage of development suitable for processing.

MATERIALS AND METHODS

The experiment included four cultivars of scallop squash developed by the Polish breeders (Disco, Gagat, Okra, Polo F₁) and Sunny Delight F₁, developed by Seminis Vegetable Seeds Company. A field study was conducted in 2012-2013 on a sandy clay soil with 1.8% organic matter and pH 7.1. Seeds of all tested cultivars were sown on 13-16 of May in spacing 1.0 × 0.8 m to the soil containing standard level of phosphorus and potassium, which available forms equaled 80 mg P and 200 mg K per 1 dm³. The required doses of these nutrients were established on the basis of annual chemical analysis of soil samples. Triple superphosphate and potassium sulphate used as the sources of these nutrients were applied 3-4 days before planting and mixed with the soil by harrowing. Nitrogen in the amount of 120 kg N·ha⁻¹ was applied in the single pre-plant dose in the form of ammonium nitrate. Samples of 30 fruit with diameter 3-6 cm, harvested in the time of maximum fruiting (end of July), were used for chemical analysis or placed in the cold storage room at temperature 7 °C and relative air humidity > 95%, and stored for the period of 1 or 2 weeks.

In both evaluated storage periods there were determined the weight loss of fruit and changes of their nutritional value. At the time of harvest and during storage, the contents of dry matter (drying at 105 °C to constant weight), total and reducing sugars (Loof-Schoorl method), vitamin C (Tillman's method), carotenoids (spectrophotometric method) according to Rumińska et. al. (1985), total polyphenols (Folin-Ciocalateu method) according to Slinkard and Singleton (1977), and nitrates by the amount of NO₃-N (ion – selective method) were analyzed.

All chemical analysis were performed in triplicate using 15 fruit in each replication of particular treatment. The obtained data, shown as means for two years of the study, were subjected to statistical evaluation on the basis of analysis of variance for two factorial design, including the cultivars and the evaluated terms of storage. The least significant differences calculated by Tukey test at significance level $\alpha = 0.05$ did not prove any interaction and for this reason are shown separately for the cultivars in each storage period.

RESULTS AND DISCUSSION

The effect of evaluated factors on weight loss as well as chemical fruit composition were similar in subsequent years of the study, so the obtained data are presented as the means for 2012-2013.

Scallop squash fruit harvested in early stages of maturity are most valuable for the fresh market as well as for food processing industry. However, such small size fruit with diameter 3-6 cm have only a short period of storage life due to high respiration and transpiration rates. Irrespective of the tested cultivar, the average weight loss equaled 6.56% after seven days of storage and increased to 11.83% after two weeks (Table 1). Taking into account the overall appearance, especially the visual symptoms of wilting, the storage period of such fruit should not exceed 7 days even at optimum temperature condition. This finding is in agreement with Grzeszczuk (2009) statement, indicating that even more matured fruit with diameter 6-12 cm could not be successfully stored longer than for 10 days and only in the case of wrapping in PCV film this period may be prolonged to 30 days.

Height differences were observed in storage ability among evaluated cultivars of scallop squash. The best external appearance after storage for one week showed 'Disco' and 'Okra', which was associated with lowest weight loss equal to 1.93% and 4.17%, respectively (Table 1). Much less suitable for even such short period of cold storage were 'Sunny Delight F₁' and 'Gagat', which weight loss at this term exceeded 9.0%. In the other study conducted by Gajewski (1995) 'Gagat' was equally suitable for the storage as 'Disco'.

A low storage ability of summer squash cultivars with yellow skin like ‘Sunny Delight F₁’ was reported by Sherman et al. (1987) and Gajewski and Grzeszczuk (2005). Only a little better results were noted in short storage of ‘Polo F₁’. After 14 days of storage, the weight loss of tested cultivars increased to 9.95 – 13.92%, which was associated with further decrease of fruit quality, due to poorer flesh firmness and visual symptoms of wilting.

Chemical composition of scallop squash fruit changed substantially during cold storage. Irrespective of the cultivar, there was observed a gradual decrease of dry matter and total sugar contents

along with prolongation the period of storage. Similar effect occurred in the case of total and reducing sugars (Table 1 & 2). Decrease of dry matter content during storage of scallop squash fruit was also reported by Gajewski (1995), while sugars by Rożek et al. (1996) and Cebula et al. (2004) in long lasting storage of cabbage. Enhancement of dry matter, while no change in total and reducing sugars after two weeks storage of Disco, Gagat and Polo F₁ cultivars were observed by Grzeszczuk and Falkowski (2003) in small size fruit of scallop squash. However, in the more developed fruit, the content of total and reducing sugars even increased during short period of storage.

Table 1. Weight loss and dry matter content in scallop squash fruit depending on the period of storage

Cultivar	Weight loss (%)		Dry matter (%)		
	Period of storage (days)				
	7	14	0	7	14
‘Disco’	1.93 a*	11.18 b	6.84 c	6.96 bc	6.41 c
‘Polo F ₁ ’	7.14 b	13.92 c	6.38 bc	6.22 b	6.16 bc
‘Sunny Delight F ₁ ’	9.70 c	13.70 c	6.86 c	6.84 bc	5.76 b
‘Gagat’	9.85 c	10.38 ab	6.32 b	5.98 ab	5.42 ab
‘Okra’	4.17 b	9.95 a	5.65 a	5.21 a	5.09 a
Mean	6.56 A**	11.83 B	6.41 B	6.24 B	5.77 A

*Within a column, values followed by the same small letter are not significantly different ($\alpha = 0.05$)

Significance letters are not comparable among columns

**Capital letters indicate significant differences between values included in a line

Table 2. Total and reducing sugar contents in scallop squash fruit depending on the period of storage

Cultivar	Total sugars (% f.w.)			Reducing sugars (% f.w.)		
	Period of storage (days)					
	0	7	14	0	7	14
‘Disco’	1.87 bc	1.77 c	1.67 c	1.63 c	1.70 c	1.62 c
‘Polo F ₁ ’	1.79 b	1.63 b	1.55 b	1.52 b	1.59 b	1.49 b
‘Sunny Delight F ₁ ’	1.57 a	1.45 a	1.32 a	1.39 a	1.38 a	1.25 a
‘Gagat’	1.73 b	1.64 b	1.54 b	1.62 c	1.60 b	1.46 b
‘Okra’	1.91 c	1.84 d	1.72 c	1.73 d	1.78 d	1.65 c
Mean	1.77 C	1.67 B	1.56 A	1.58 B	1.61 B	1.49 A

Note: See Table 1

Table 3. Vitamin C and carotenoids content in scallop squash fruit depending on the period of storage

Cultivar	Vitamin C (mg·100 g ⁻¹ f.w.)			Carotenoids (mg·100 g ⁻¹ d.w.)		
	Period of storage (days)					
	0	7	14	0	7	14
‘Disco’	21 b	19 b	14 ab	0.81 a	0.33 a	0.34 a
‘Polo F ₁ ’	22 b	20 b	15 b	1.00 a	0.35 a	0.31 a
‘Sunny Delight F ₁ ’	27 c	25 c	22 c	0.91 a	0.97 b	0.82 d
‘Gagat’	17 a	14 a	11 a	1.66 b	1.57 c	0.73 c
‘Okra’	16 a	16 a	14 ab	1.70 b	1.64 c	0.50 b
Mean	21 C	19 B	15 A	1.22 C	0.97 B	0.54 A

Note: See Table 1

Table 4. Total polyphenols and nitrates content in scallop squash fruit depending on the period of storage

Cultivar	Polyphenols (mg·100 g ⁻¹ f.w.)			Nitrates (mg·kg ⁻¹ f.w.)		
	Period of storage (days)					
	0	7	14	0	7	14
‘Disco’	148 b	200 d	96 a	459 b	142 a	100 a
‘Polo F ₁ ’	126 b	163 c	128 b	436 b	269 b	215 b
‘Sunny Delight F ₁ ’	144 b	126 b	122 b	269 a	189 b	140 b
‘Gagat’	82 a	93 a	89 a	546 c	199 b	178 b
‘Okra’	76 a	89 a	89 a	525 c	173 ab	150 b
Mean	115 B	134 C	105 A	447 C	194 B	157 A

Note: See Table 1

'Sunny Delight F₁', which is widely used for food processing, appeared to be the richest source of vitamin C at the time of harvest and at the subsequent terms of storage as well (Table 3). Substantially lower content of vitamin C, if compared to the other tested cultivars, was found in 'Okra', similarly as in 'Gagat' (Grzeszczuk and Falkowski 2003). The other favorable feature of 'Sunny Delight F₁' was significantly lower tendency to nitrates accumulation and high amounts of polyphenols at the time of harvest (Table 4). Similarly high polyphenols amount contained 'Disco' and 'Polo F₁' fruit directly after harvest (Table 4). However, both these cultivars were rather poor source of carotenoids when evaluated at harvest or after 1 or 2 weeks of cold storage (Table 3). Initial high level of nitrates in 'Disco' fruit showed a huge decrease during storage to the amounts far below to that occurred in 'Sunny Delight F₁' (Table 4). Total and reducing sugar

contents were significantly dependent on cultivar (Table 2). The highest amounts of these compounds were observed in 'Okra', while significantly lowest in 'Sunny Delight F₁'. Taking into account the content of vitamin C and polyphenols as well as high tendency for nitrates accumulation, the nutritional value of 'Okra' and 'Gagat' was lower if compared to the other evaluated cultivars. In term of 'Gagat' this finding is in agreement with Grzeszczuk (2004) statement.

Scallop squash fruit are being considered as a rich source of vitamin C, which amount, depending on the cultivar, may exceed the level of 30 mg·100 g⁻¹ f.w. (Mazurek & Niemirowicz-Szczyt 1992) and is highly affected by the size of fruit. According to Lester (2006), in general, ascorbic acid content decreases with increasing the size of vegetables at harvest, and this statement was confirmed in the trials with scallop squash (Gajc-

Wolska & Skąpski 1994; Grzeszczuk 2007; Balbierz & Kołota 2013). In our study, its average content in small size fruit with a diameter of 3-6 cm decreased gradually from 21 at the time of harvest to 19 and 15 mg·100 g⁻¹ f.w. after one and two weeks of storage, respectively (Table 3). These data are in agreement with most of the available information indicating vitamin C as the most sensitive compound to postharvest losses (Lee & Kader 2000). During storage, vitamin C easily becomes oxidized, especially when the acidity level decreases (Wierzbicka & Kuskowska 2002) and for this reason in vegetables is greater than in acidic fruits, for example in citrus (Lee et al. 2000). Among vegetables, minimum or no losses of ascorbic acid during storage has been reported in cruciferous species (Cebula et al. 2004; Grabowska et al. 2007) due to high retention of total sulphur and glutathione. In the other study conducted by Grzeszczuk and Falkowski (2003), the content of vitamin C after two weeks of storage decreased by 2.2 mg 100 g⁻¹ f.w. in comparison to the initial value. Similar effect of short storage on content of this compound in fruit of zucchini squash of different maturity was reported by Gajewski (1995). The losses of vitamin C after harvest, can be reduced by the storage of different horticulture crop fruits in reduced oxygen and enhanced in CO₂ atmosphere (Lee & Kader 2000). On the other hand, conditions, which are favorable for wilting may result in rapid losses of vitamin C.

The other important antioxidant compounds present in scallop squash fruit are carotenoids and polyphenols. Irrespective of the cultivar, initial carotenoids content amounted to 1.22 mg·100 g⁻¹ f.w., significantly decreased during the storage by 20.5% and 55.7% after 7 and 14 days, respectively. In the case of polyphenols, there was observed their significant increase after 7-day period of storage, and drop below their initial level after 14 days (Table 4). The increase of polyphenols concentration with the storage period was also observed in different vegetable crop species, such as lettuce (Michalek et al. 1996), sweet pepper (Kołton et al. 2011; Kamińska & Leja 2013) and eggplant (Gajewski & Arasimowicz 2006). In the trial conducted by Gajewski and Rosłon (2002) on zucchini squash, two week period of fruit storage caused loss of carotenoids by about 30-40%, and increase of polyphenols by 40%.

It was concluded that, higher temperature during storage was favorable for the content of both these components. The increase of polyphenols after two weeks of cold storage in scallop squash fruit was also observed by Grzeszczuk (2009), and this phenomena may be explained by their release from lignins and tannins in hydrolysis processes.

Nitrates content significantly declined during the storage of scallop squash fruit in all five cultivars (Table 4) and this finding is in agreement with Gajewski (1995) statement. In the study conducted by Czech and Rusinek (2012), changes in nitrates content during storage varied greatly, depending on plant species. In the case of savoy cabbage and Brussels sprouts, there was observed a drop of nitrates content for the period of 5 months storage by about 65%, while two fold increase in the heads of Chinese cabbage. Smaller, but still significant nitrates enhancement during storage was noted in white head cabbage. Study conducted with sweet pepper shown decrease of nitrates content during storage of green color fruits, while no change was found in red color ones (Kołton et al. 2011).

CONCLUSION

1. Seven or fourteen days of fruit storage of scallop squash caused a substantial loss of weight, while decrease of dry matter, sugars, vitamin C, carotenoids and nitrates contents.
2. Good quality of small size fruit of scallop squash can be maintained during 7 days of storage period, and the most suitable for this purpose are Disco and Okra cultivars.
3. 'Sunny Delight F₁', which can be appreciated for its high amounts of vitamin C and polyphenols and low tendency to nitrates accumulation, similar to 'Gagat' and 'Polo F₁' showed lower suitability for short period of cold storage.

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