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Fruit composition of organically and conventionally cultivated strawberry 'Polka'

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Abstract. The aim of this study was to elucidate the effect of cultivation technology and plant age on fruit composition of strawberries (*Fragaria* x *ananassa* Duch*.)* 'Polka'. Strawberry fruits from two- and three-year-old plantations were harvested on two conventional and two organic farms in South Estonia in 2008. Content of fruit dry matter (DM), ascorbic acid content (AAC), soluble solids content (SSC), titratable acidity (TA), anthocyanins (ACY) and total antioxidant capacity (TAC) were recorded. The results indicate that the strawberries cultivated under organic farming conditions had higher SSC and contained more fruit DM, compared to the conventionally grown strawberries. Content of ACY and SSC was significantly influenced by plant age.

Key words: soluble solids/titratable acid ratio, ascorbic acid, anthocyanins, total antioxidant activity

INTRODUCTION

Several studies have shown that consumers have positive attitude towards organic food (Loureiro et al., 2001; Magnusson et al., 2001). Organic foods are associated with no concern, no risks and are seen as healthy (Koivisto Hursti & Magnusson, 2003).

Despite the growing interest of consumers towards organic food, there is either a lack of information or contradictory information in scientific literature about the quality of organically versus conventionally grown fruits and vegetables. Häkkinen & Törrönen (2000) found similar levels of flavonols and phenolic acids in the cultivars 'Polka' and 'Honeoye' when organic and conventional cultivation techniques were used. Asami et al. (2003) have reported that in strawberries grown under sustainable conditions, the ascorbic acid content was 20% higher than in conventionally-grown fruit. Differences in reported data indicate that cultivation technologies affect certain bioactive compounds, but do not affect others. Also, cultivar differences, climate and plant age should be considered.

The objective of the current study was to elucidate the effect of organic and conventional cultivation technology on fruit composition and total antioxidant activity of strawberry 'Polka' fruits from two- and three-year-old plantations.

MATERIALS AND METHODS

Strawberry fruits from two- and three-year-old plantations were harvested on 30 June 2008 from two conventional and two organic farms. All farms were situated in

Tartu County, South Estonia, where brown pseudopodzolic soils dominate. The longest distance between the farms was 48 km and the exact coordinates of farms were as follows: conventional 1: NL 58º15'33''; EL 26º35'33''; conventional 2: NL 58º27'12''; EL 26º50'39''; organic 1: NL 58º29'15''; EL 26º45'52''and organic 2: NL 58º36'02''; EL 27º05'48''. Weather conditions in 2008 were not favourable for strawberry growth and fruit ripening. May 2008 was dry – only 31 mm of rain was recorded while the average rainfall for many years is 55 mm. In June the amount of precipitation was almost twice the month's average (108 mm and 66 mm, respectively). Mean air temperature was at about the same level as the long-term average (10.8ºC and 14.6ºC in May and June 2008 versus 11.0ºC and 15.1ºC as average for many years). Fruit quality parameters were determined from fresh fruits on the day of harvest. For determination of AAC, ten randomly chosen fruits from each plot were cut into sectors, weighed into titration vessel, and extraction solution was added. The sectors were crushed quickly with homogenizator and titrated with dichlorophenolindophenol; also voltamperometric indication was used (method M569/570 (www.mt.com)). TA was determined by titration to pH 8.2 with 0.1 NaOH. Titrator Mettler Toledo DL50 with autosampler Rondolino was used for titration of AAC and TA. SSC (%) was measured using the digital refractometer ATAGO CO., Ltd., Japan. For determination of ACY, 10 whole fruits in three replications from each variant were crushed and 10 g of crushed fruit soaked in an extracting solution containing HCl (0,1M):C_2H_5OH (96%) = 15: 85 (v/v). The content of total anthocyanins was estimated by a pH differential method (Cheng & Breen, 1991). Results were expressed as milligrams of pelargonidin-3-glucoside equivalent per 100 g fresh weight.

TAC was determined using the 1.1-diphenyl-2-picrylhydrazyl (DPPH) discoloration assay described by Brand-Williams et al. *(*1995) with some modifications. Results of TAC are reported as mg ascorbic acid per 100 g fruit fresh weight, as suggested by Kim et al. (2002).

Significant differences between individual farms, plant age and cultivation practices were tested by two-way analysis of variance at significance level of $P \leq 0.05$. Significance of differences ($P \leq 0.05$) of the individual farms, average effect of cultivation technology and average effect of plant age were determined separately. In Figures and Tables mean values followed by the same letter are not significantly different at $P \leq 0.05$.

RESULTS AND DISCUSSION

Fruit DM ranged from 10.4 to 12.2% in the 2-year-old plantation and from 10.8 to 11.4% in the 3-year-old plantation (Table 1). Although there was quite a large variation in fruit DM between individual farms, the average effect of cultivation techniques could be distinguished. In the 2-year-old plantation there was a tendency that organically grown strawberries (further referred to as O-strawberries) contained more DM while in the 3-year-old plantation O-strawberries had significantly higher content of fruit DM compared to the conventionally cultivated fruits (further referred to as C-strawberries). Average effect of plant age on fruit DM was not significant (data not shown).

Table 1. Fruit quality characteristics on individual farms of organically and conventionally cultivated strawberries'Polka' in Southern Estonia in 2008.

Cultiv. Technol.	DM %	SSC %	TA %	SSC/TA	AAC mg 100 g FW^{-1}	ACY mg 100 g FW^{-1}	TAC mg AA 100 g FW^{-1}
Two-year-old plants							
Organic 1	12.2b	10.7a	0.92c	11.7a	50d	19.4bc	70.4a
Organic 2	11.3bc	9.2b	1.03a	8.9c	53c	36.9a	63.2c
Conv. 1	10.4c	8.8c	1.00b	8.8c	60a	24.6b	67.5b
Conv. 2	11.9b	10.3a	1.02ab	10.0b	58b	17.4c	59.0d
Three-year-old plants							
Organic 1	11.4b	11.8a	1.07a	10.3b	60a	15.7bc	75.5a
Organic 2	11.3b	11.1ab	1.03ab	10.8b	53b	24.2a	63.1b
Conv. 1	10.8c	9.3c	1.01b	8.9c	44c	11.6c	58.2c
Conv. 2	11.1bc	10.0c	0.79c	12.3a	60a	21.3ab	54.7d

SSC also differed between fruits from different farms (Table 1). Average SSC of O-strawberries in the 2-year-old plantation was 9.9% and that from the three-year-old plantation 11.5%, which was significantly higher in both cases compared to C-strawberries (SSC 9.5 and 9.7%, respectively). Fruits from the 3-year-old plantation had higher SSC compared to fruits from a younger plantation. Strawberry TA ranged from 0.92 to 1.07%, and was affected neither by the cultivation technology nor by plant age (Table 1).

SSC/TA was significantly higher in O-strawberries from the 2-year-old plantation and in the 3-year-old plantation there was a tendency towards increased SSC/TA in O-strawberries. Investigations showed that the ratio SSC/TA is one of the predictors of the sweetness, sourness and flavour intensity of strawberry fruit (Gunnes et al., 2009). Thus, our results indicate that the C-strawberry taste tends to be more acidic and less sweet compared to O-strawberries. Schöpplein et al. (2002) found that the sensory popularity of strawberry cultivars correlated positively with fruity odour, sweet and aromatic taste, but negatively with watery taste. Average effect of plant age was also significant – strawberries from an older plantation had higher SSC/TA compared to fruits from the 2-year-old plantation (Fig.1).

AAC of 'Polka' strawberries ranged from 44 to 60 mg 100 g FW^{-1} (Table 1), which is consistent with previously reported values for 'Polka' of 62 and 48 mg 100 g FW^{-1} in 1997 and 1998 (Hakala et al., 2003). Average effect of cultivation techniques was contradictory in plantations from different ages – in the 2-year-old plantation O-strawberries had lower AAC (52 mg 100 g FW^{-1}) compared to C-strawberries (59 mg 100 g FW^{-1}) (Fig.2). In the 3-year-old plantation average AAC content was 52 and 57 mg 100 g FW^{-1} in conventionally and organically cultivated strawberries, respectively, being significantly higher in O-strawberries. Hakala et al. (2003) have reported that organic cultivation had no effect on the content of vitamin C in the varieties 'Polka', 'Honeoye' and 'Jonsok'. In our previous experiments with strawberries cultivated with plastic and straw mulch, we also found that influence of cultural practices on vitamin C content was different in different years (Moor et al., 2005). Thus, all the above mentioned results indicate that ascorbic acid content is not easily influenced by cultural practices.

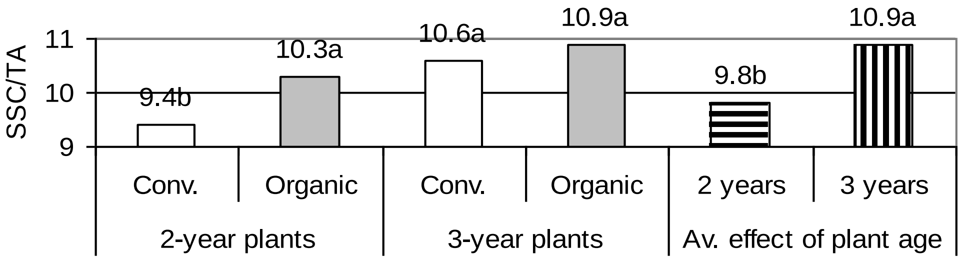

Fig. 1. Average effect of conventional and organic cultivation and plant age on strawberry 'Polka' SSC/TA. *LSD* for 2-year plants, 3-year plants and for average effect of plant age, respectively: 0.5; 0.8 and 0.4.

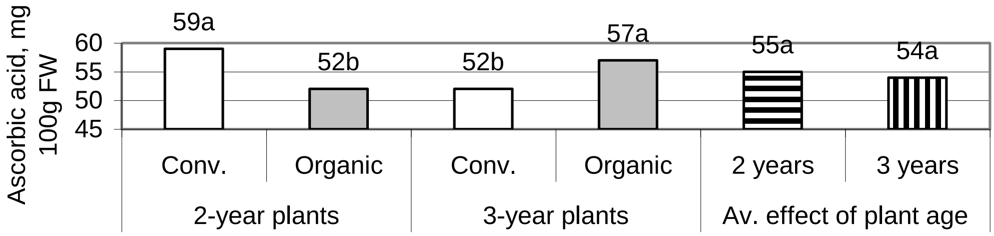

Fig. 2. Average effect of conventional and organic cultivation and plant age on strawberry 'Polka' AAC. *LSD* for 2-year plants, 3-year plants and for average effect of plant age, respectively: 1; 1 and 2.

Strawberry ACY content in the current experiment ranged from 12 to 37 mg 100 g FW^{-1}, whereas the differences between individual farms were very large (Table 1).

ACY content was significantly higher in O-strawberries from the 2-year-old plantation while in the 3-year-old plantation there was a tendency for increased ACY in O-strawberries (Fig. 3). Average effect of plant age on ACY content was also significant – fruits from the 3-year-old plantation had lower ACY content compared to a younger plantation. Strawberry TAC ranged from 55 to 76 mg 100 g FW^{-1}mg (Table 1). Even though the variation between farms was considerable, the average effect of cultivation technology was significant – both in the 2- and 3-year-old plantations O-strawberries had significantly higher TAC compared to C-strawberries (Fig. 4).

Our results support the data reported by Olsson et al. (2006), who found a significantly higher inhibition effect of cancer cell proliferation by the organically cultivated strawberries. As TAC values obtained by the method used in this study should express the sum of antioxidant properties of different antioxidant compounds, it should be expected that TAC correlates with AAC and ACY content. Based on correlation analysis results, however, significant correlation was observed neither between TAC and AAC nor between TAC and ACY content (data not shown). Similar findings were reported by Gil et al. (2002), who found that antioxidant properties determined by DPPH method had no correlation with AA content in different stone fruits.

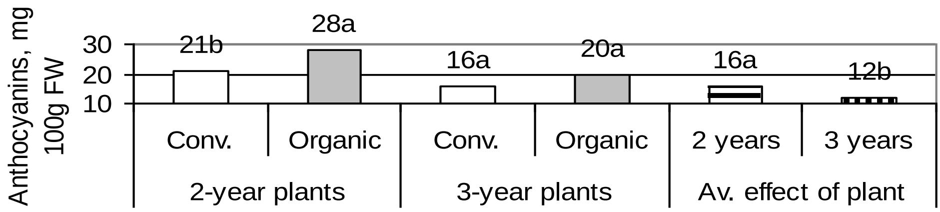

Fig. 3. Average effect of conventional and organic cultivation and plant age on strawberry ‘Polka’ ACY content. *LSD* for 2-year plants, 3-year plants and for average effect of plant age, respectively: 6; 5 and 3.

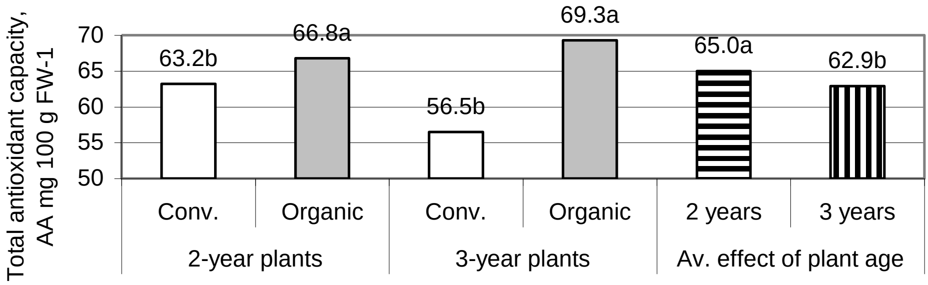

Fig. 4. Average effect of conventional and organic cultivation and plant age on strawberry ‘Polka’ TAC. *LSD* for 2-year plants, 3-year plants and for average effect of plant age, respectively: 0.4; 0.3 and 0.2.

Although pelargonidin-3 glycoside is the main phenolic compound in strawberries (Proteggente et al., 2002; Yoshida et al., 2002), there are also other compounds, e.g. p-coumaric glucose, cinnamoyl glucose, quercetin-3-glucoside, kaempferol-3-glucoside (Proteggente et al., 2002) and (+)-catechin (Törrönen & Määttä, 2002). Content of the last mentioned phenolic compounds was not determined in our study, nevertheless these compounds could also contribute to the total antioxidant activity. Wu et al. (1998) have assumed that a synergistic effect could exist between different antioxidants, meaning that the total antioxidant effect may be greater than the sum of individual antioxidant activities.

CONCLUSIONS

Organically cultivated strawberries tended to have higher SSC/TA, indicating that the taste of organically grown strawberries could be somewhat sweeter. Noteworthy is the finding that the total antioxidant capacity of organically grown strawberries was significantly higher although the content of the major antioxidants – ascorbic acid and anthocyanins – did not show any increase. This phenomenon can be attributed to either a possible synergistic effect of different antioxidants or to other antioxidant compounds which were not determined in the current study. Plant age had a significant influence on fruit SSC and SSC/TA, ACY content and TAC, indicating that its effect on fruit quality parameters is even larger than that of cultivation technology, and it should be considered in comparative studies.

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