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EFFECTS OF ORGANIC AND CONVENTIONAL CULTIVATION METHODS ON MINERAL CONTENT AND TASTE PARAMETERS IN TOMATO FRUIT

SUMMARY

Three tomato varieties (Robin-F_1, Amati-F_1 and Elpida-F_1) were grown in the greenhouse condition (Northeastern Greece) using organic and conventional cultivation methods. The differences between production systems were in the pest control and fertilizer. We used goat manure (30 t ha^{-1}) in organic system and 400 kg/ha slow release mineral fertilizer NPK 12-12-17 + 2MgO + 8S + trace elements in conventional growing system. The objective of this study was to investigate whether there were any differences in the TSS, citric acids and mineral content (K, Ca, Na, Mg, Fe, Zn, Mn, Cu) in organic and conventional tomatoes.

The differences were more dependent on the cultivars than on the production system. The cultivar 'Elpida' had the highest content of micronutrient compared to the two other varieties grown under the same conditions. We found significantly greater concentrations of P, K, Ca and Mg in organic tomatoes but in conventionally grown tomato we found greater content of Zn, Fe and Cu. Growing method have no influence on concentrations of B and Mn in tomato fruit. 'Elpida' cultivar had the highest content of TSS and citric acid (0.48%) of the three different varieties grown under same conditions. Also, the taste index in organic 'Elpida' (1.10) was much more pleasant because the ratio of total soluble solid and total acid more favorable than the tomatoes from conventional production.

Keywords: tomato, production, organic, conventional, micronutrients.

INTRODUCTION

The nutritional quality of organic and conventional products has been evaluated mainly in terms of macronutrients, vitamins and mineral contents. The results of over 150 studies reviewed (Woese *et al,* 1997) demonstrated inconsistent differences in nutritional quality of conventional and organic produced vegetables. Moreover, Heaton (2001) considered some 400 previous papers comparing organic and conventional foods and concluded that organic foods appear to be higher in vitamin C and some essential minerals. Using

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statistical methods, Worthington (2001) showed that organic crops contained significantly more vitamin C, iron, magnesium and phosphorus than conventional crops.

The tomato (*Solanum lycopersicum* L.) is one of the world's most important vegetables, with an estimated total production of about 141.40 million tonnes in 2009 (FAOSTAT 2009). It is the second most widely consumed vegetable after the potato, with an average annual per capita consumption of 12 kg (Lugasi *et al*, 2003). In the human diet, it is an important source of micronutrients, notably lycopene, ß-carotene, a-tocopherol, phenolic compounds, certain minerals (notably potassium) and carboxylic acids, including ascorbic, citric, malic, fumaric and oxalic acids (Caputo *et al*, 2004; Hernandez Suarez *et al*, 2007). The benefits of tomatoes and tomato products have been attributed mostly to the significant amount of lycopene contained, which constitutes 80-90% of the total carotenoid content in tomatoes. Increased interest in organic tomato production imposed the need to evaluate the quality and nutritional value of organic tomato. One major problem in comparative studies might be that genuine organic and conventional production systems differ in many factors and that a simple measurement of food composition does not reflect its quality. Other scientists have argued that a valid comparison of nutritional quality would, for example, require that the same cultivars are grown at the same location, in the same soil and with the same amounts of nutrients. The effect of variety, season, harvest time, maturity, as well as environmental factors such as light, water and nutrient supply on the antioxidant content of tomatoes are reviewed by Dumas *et al* (2003). Kelly and Bateman (2010) found significantly greater concentrations of minerals in organic tomatoes. The absence of proven differences in nutritional properties between organic and conventional products may be attributed at least in part to methodological issues. For example, many studies of organic and conventional products have compared different crop varieties (i.e. genetically different products) or crops grown in different locations (thus introducing environmental variation) or crops managed in ways that differed in aspects that are not intrinsically part of the difference between organic and conventional production (e.g. harvesting time, postharvest handling and storage conditions (Bourn and Prescott, 2002; and Caris Veyrat *et al*, 2004). Therefore, the aim of our study was to compare the content in some microconstituents of tomato fruits collected from organic and conventionally production system.

In Sweden, Lundegardh and Martensson (2003) carried out an experiment over three years on the effect of cultivation methods on tomato quality. The results showed that organically produced tomatoes contained a higher level of vitamin C, lycopene and chlorine than conventionally cultivated ones. Research carried out by Borguini and Torres (2006) shows that tomatoes coming from organic cultivation procedures presented higher vitamin C content than the fruit by conventional cultivation. Significantly higher vitamin C content was observed with red shade netting technologies (Milenković *et al*, 2012).

Chassy *et al* (2006) reported, as well, a statistically significant higher content of ascorbic acid in organic tomatoes compared with conventional ones. Heeb (2005) in her Doctoral thesis found different levels of the nutritional compounds she investigated in every year of her studies on tomatoes. Heeb concluded that organic production methods by definition did not guarantee a higher quality product. In order to obtain uniform higher quality standards it is necessary to understand the processes influencing the chemical composition of vegetables - in this case tomato. The factors influencing tomato quality are complex and interrelated, and additional studies are necessary to consolidate the knowledge about the real interdependences.

Organic tomatoes achieve higher prices than conventional ones, because these products are often linked to protecting the environment and to having better quality (taste, storage) and most people believe that they are healthier. Research results on the effects of organic and conventional production on fruit quality are sometimes contradictory. In terms of quality, some studies report better taste, higher vitamin C contents and higher levels of other quality related compounds for organically grown products (Mitchell *et al*, 2007; Caris-Veyrat *et al*, 2004), whereas several other studies have found the opposite or no differences in quality characteristics between organically and conventionally grown vegetables (Caris-Veyrat *et al*, 2004). The identification of cultivars with high nutritive value, represent a useful approach to select tomato cultivars with better health-promoting properties. During tomato fruit ripening, a series of quantitative and qualitative changes take place, changing tomato flavor and aroma volatile profiles (Baldwin *et al*, 1991).

The aims of this paper were to determinate the content of several major chemical compounds in different tomato cultivars which contribute to the nutritive quality of the tomato and to evaluate the change of the chemical composition according to the cultivation method.

MATERIAL AND METHODS

Experimental design and plant material

Three tomato varieties (Robin F_1, Amati F_1 and Elpida F_1) have been tested in greenhouse production (plastic tunnels 3.5m high, covered with termolux 180 μm) during 2008-2010, located in the Sapes, Northeastern Greece, using two different growing systems: organic and conventional. Greenhouse technology and horticultural practices differ little. The main variations concerned pest control, fertilization and fertility of soil, which was of much better quality in the organic production. In conventional cultivation mineral fertilizers and chemical plant protection were applied. Tab 1.

The differences between production systems were the fertilizers used (organic: goat manure 3t/ha; conventional: mineral fertilizer NPK (12:12:17), nitrophos blue special + 2MgO +8S +Trace elements – 400 kg/ha), the number of phytosanitary (solarization) treatments (larger in organic system), the pesticide types applied (preventive in the organic systems and preventive or healing with variable period of effectiveness in the conventional one). It was an early-medium production; planting was done between April 15 and April 20 at a density of 2.64 plants/m^2.

Table 1. Chemical analysis of soil in conventional and organic production

Production system	Soil depth (cm)	pH		$CaCO_3$ %	Humus %	N total %	P_2O_5 %	K_2O %
		KCl	H_2O					
Conventional	0-20	6.46	7.70	2.10	1.28	0.08	25.20	15.68
	20-40	5.89	6.87	3.36	1.38	0.09	15.79	26.99
	40-60	5.42	6.50	2.52	0.95	0.06	7.89	26.54
Organic	0-20	6.00	6.46	2.94	6.73	0.44	179.35	37.36
	20-40	5.99	6.62	2.10	1.96	0.13	51.62	62.21
	40-60	5.72	6.71	3.36	1.39	0.09	22.04	37.81

Quality trail

At the pink stage of ripening determined by visual inspection, samples were collected for quality analyses (color, firmness, total soluble solids, total sugar, total acidity content of vitamin C, content of carotenoids and lycopene). For sensory evaluation fruits were evaluated by trained descriptive panelists on the day of harvest (red stage). Tomato samples (20 fruits) were collected each year from June till August and were taken from the third to sixth floral branches. All analyzes were carried out in the Technological Faculty of Novi Sad and the Analytical Laboratory of Biolab Epirus (Tzimas s. Bioepirus Ltd), Ioannina – Greece. Determination of total soluble solids (TSS) was measured by a refractometer. The results were reported as ^{o}Brix at 20 ^{o}C. The titrable acidity (TA) was measured with 5 ml aliquots of juice that were titrated at pH 8,1 with 0,1N NaOH (required to neutralize the acids of tomatoes in phenolphthalein presence) and the results were expressed as citric acid percentages.

Determination of mineral elements

Approximately 0.5 g of freeze-dried sample was weighed into porcelain crucibles that had previously been heated for 3 h at 550^o C and was converted to white ash at this same temperature over 12–18 h. Each ashed sample was dissolved in 20 mL of 3 m HCl, and K, Ca, Na, Mg, Fe, Zn, Mn and Cu were determined by atomic absorption spectrophotometry.

Taste and maturity index

Besides, a taste index and the maturity were calculated using the equation proposed by Navez, Letard, Graselly, and Jost (1999) and Nielsen (2003) starting from the Brix degree and acidity values which were determined in a previous paper (Hernandez *et al*, 2007).

$$\text{Taste index} = \frac{\text{Brix degree}}{20 \text{ x acidity}} + \text{acidity}$$

$$\text{Maturity} = \frac{\text{Brix degree}}{\text{acidity}}$$

Chemicals

All chemicals and reagents were of analytical grade and were purchased from Sigma Chemical Co. (St Louis, MQ, USA), Aldrich Chemical Co. (Steinheim, Germany) and Alfa Aesar (Karlsruhe, Germany).

Data analysis

All statistical analyses were performed using SAS procedure (SAS Institute, Cary, NC) for analyses of variance. Means were compared by Tukey's multiple range test.

RESULTS AND DISCUSSION

Mineral contents

Growing method and cultivar had significant influence on K, Ca, Na or Mg contents (Table 2). The main factor influencing tomato micronutrient content was cultivar (Ordonez-Santos *et al*, 2011). Our results showed that the potassium content in organic tomatoes (153.05-164.31 $mg100g^{-1}$) was higher than in conventional tomatoes (126.79-142.54 $mg100g^{-1}$). Organically grown 'Elpida' produced the highest level of potassium in fruit (164.31 $mg100^{-1}g$) comparing to the other two cultivars. Potassium concentrations were similar to those (191.42–236.54 $mg \cdot 100g^{-1}$) reported by Loiudice *et al* (1995) and by Hernandez Suarez *et al* (2007), but higher than those measured by Gundersen *et al* (2001).

Our results showed that the calcium content in organic tomato (8.08-9.00 $mg \cdot 100g^{-1}$) was higher than in conventional tomatoes (7.84-8.58 $mg \cdot 100g^{-1}$). Calcium concentrations reported by Ordonez-Santos *et al* (2011) were higher (15.97–23.13 $mg \cdot 100g^{-1}$) than those found in our studies. Kelly and Bateman (2010) found significantly greater concentrations of Ca and Mg in organic tomatoes and Perez-Lopez *et al* (2007) found significantly greater concentrations of these minerals in organic clementine mandarin fruit.

Magnesium concentrations in organic (17.36-22.22 $mg \cdot 100g^{-1}$) and conventional tomato (18.75-19.16 $mg \cdot 100g^{-1}$) were higher than those found by Ordonez-Santos *et al* (2011) (10.30–11.88 $mg \cdot 100g^{-1}$), Loiudice *et al* (1995) and Gundersen *et al* (2001), but similar to those of Hernandez Suarez *et al* (2007).

The ranges of measured iron concentration in this study 0.51-0.64 in organic and 0.69-0.72 $mg \cdot 100g^{1}$ in conventional tomato respectively. Iron concentration reported by Ordonez-Santos *et al* (2011) were higher 0.54–1.37 $mg \cdot 100g^{-1}$. We observed no significant influence of growing method, which in the case of iron is in keeping with the findings of Rodrıguez *et al* (2001). On the contrary, Perez-Lopez *et al* (2007) found significantly greater concentrations of these minerals in organic clementine mandarin fruit, and Kelly and Bateman (2010) found significantly greater concentrations of these minerals in organic tomatoes. Between-cultivar variation in these micronutrients was also reported by Ruiz *et al* (2005) and Anza *et al* (2006).

Copper concentration (0.11-0.13 $mg \cdot 100g^{-1}$) in conventional tomatoes was higher than in organic tomato (0.5-0.7 $mg \cdot 100g^{-1}$). The ranges of measured copper concentrations (0.05–0.11 mg·100g^{-1}) in study by Ordonez-Santos *et al* (2011), were higher than those reported by Gundersen *et al* (2001) and Hernandez Suarez *et al* (2007).

Table 2 : Mineral contents of conventionally and organically grown ‘Elpida´, ‘Robin’ and ‘Amati’ tomatoes

	Moisture %	Total N	P	K	Ca	Mg	B	Mn	Zn	Fe	Cu
		(mg·100g^{-1} fresh weight)									
		Conventional production									
Elpida	93.19	191.80	33.74	126.79	7.84	18.75	0.02	0.08	0.19	0.69	0.11
Robin	94.28	214.32	29.18	137.59	8.58	19.16	0.03	0.09	0.18	0.73	0.10
Amati	93.62	223.41	27.10	142.54	8.29	18.81	0.03	0.08	0.19	0.82	0.13
		Organic production									
Elpida	93.27	218.77	43.43	164.31	8.08	22.22	0.03	0.08	0.17	0.64	0.07
Robin	92.86	248.73	46.75	159.17	8.92	22.13	0.03	0.08	0.16	0.59	0.05
Amati	93.57	193.02	45.34	153.05	9.00	17.36	0.03	0.07	0.18	0.51	0.05

We observed no significant differences in zinc concentrations between organic (0.16-0-18 mg·100g^{-1}) and conventional tomatoes (0.18-0.19 mg·100g^{-1}). Zinc concentrations (0.14–0.33 mg·100g^{-1}) reported by Ordonez-Santos *et al* (2011) were higher than those reported by Gundersen *et al* (2001) and Hernandez Suarez *et al* (2007). Like Rodrıguez *et al* (2001), we found growing method to have no influence on zinc content. On the contrary, Perez-Lopez *et al* (2007) found significantly greater concentrations of Zn in organically grown clementine mandarin fruit, and Kelly & Bateman (2010) found significantly greater concentrations of Zn in organic tomatoes. The significant influence of cultivar was attributed mainly to that found among organically grown tomatoes, among which the cultivar ‘Llado´ had significantly higher zinc levels than the ‘Antillas’ cultivar (Table 2). Between-cultivar differences in zinc content have also been reported by Ruiz *et al* (2005) and Anza *et al* (2006).

We observed insignificant differences of manganese content between conventional (0.08-0.09 mg·100g^{-1}) and organic tomato (0.07-0.08 mg·100g^{-1}). Manganese concentrations (0.05–0.13 mg·100g^{-1}) found by Ordonez-Santos *et al* (2011) were similar to those reported by Gundersen *et al* (2001) and lower than those measured by Hernandez Suarez *et al* (2007) and were significantly influenced by both cultivar and growing method. Ruiz *et al* (2005) and Anza *et al* (2006) likewise found cultivar to influence Mn content. The influence of growing method was only statistically significant for ‘Llado´ ’ tomatoes, among which Mn levels were higher when organic methods were used (Tables 2). Rodrıguez *et al* (2001) found Mn levels to be unaffected by growing method. Like Rodriguez *et al* (2001), we found growing method to have no influence on zinc content (Table 2); on the contrary, Perez-Lopez *et al* (2007) found significantly greater concentrations of Mn in organic clementine mandarin fruit, but Kelly & Bateman

(2010) found significantly greater concentrations of Zn in conventional tomatoes. On the other hand, in the present study, one possible hypothesis that may explain the insignificant differences in the majority of the minerals could be that the tomato plants of the two cultivation methods managed to have similar soil conditions and irrigation. Previous studies support such a claim.

Gundersen *et al* (2001) for example, report the concentrations of Ca, Fe, Mn, Na and Zn were significantly different for tomato fruits grown on the different substrates. Hernandez Suarez *et al* (2007) report significant differences in the concentration of Na, Ca, Mg and Zn in tomato grown in two different production regions of the island of Tenerife (Spain). Some mineral contents in the tomato fruit must be influenced by the region of production, which is mainly influenced by the mineral contents of the cropping soils and of the water for irrigation (Hernandez Suarez *et al*, 2007).

On the other hand, considering the same data reported in literature, Dangour *et al* (2009), reviewing about organic food characteristics and discussing on the suggestion of a possible superiority of organic foods, reported that, in relation to mineral content (Mg, Ca, K, Zn and Cu), no significant differences could be ascribed to production procedures, even if this kind of foods seemed to contain a higher content of phosphorus and a lower of nitrate with respect to conventional ones. At the moment, it appears that more detailed studies on possible differences about mineral content in organic and conventional foods should be carried out. In relation to product quality, Barrett *et al* (2007) reported on higher content of total soluble solids (TSS), higher titrable acidity and firmness in organic tomatoes (S. lycopersicum L.) when compared with conventional ones.

Greenhouse vegetable production offers advantages compared to production at the open field with regard to quality assurance principally, because the plants are not exposed directly to the rapid changes of climate conditions (Kapoulas *et al*, 2011). An important role for this purpose is also the cultivar selection by using tomato hybrid varieties with a high yield potential and a good fruit quality. The results of the chemical analysis are presented in Table 3. Organic tomatoes contained on average at all cultivars 4.73^{o}B and at conventional 4.79 of TSS-total soluble solids in fruit. Results obtained showed that the accumulation of TSS (total soluble solid) at different organic and conventional (in average at all cultivars) cultivation system did not show any statistically significant difference. 'Elpida' tomato fruit in organic production system contained the highest level of TSS. Irrespective of the cultivation method used, 'Elpida' in average also contained the highest level of TSS (5.08^{o}Brix) in comparison to the rest of examined tomato cultivars.

The organic acid in a tomato fruit consist of mainly citric and malic acid with a range of 0.3 to 0.6% (Helyes *et al*, 1999). The obtained results showed that conventional tomatoes contained more organic acids in comparison to those cultivated by organic methods, in all periods of analysis, being approximately about 0.48%. At the same time, it should be noted that 'Elpida' tomatoes were richer in organic acids in comparison to other examined cultivars, independently from the used cultivation system (Table 3).

Table 3. Total acidity and TSS (total soluble solid) content of three tomato cultivars from organic and conventional production system

	Organic production		***Conventional*** production	
	Total acidity %	TSS Brix°	Total acidity %	TSS Brix°
Amati	0.41± 0.01c	4.83± 0.4b	0.48± 0.02 a	4.95± 0.5a
Robin	0.44± 0.01b	4.76± 0.5b	0.47± 0.02a	4.85± 0.6a
Elpida	0.47± 0.01a	5.08± 0.5a	0.48± 0.01a	4.59± 0.5b

As with the sugars, the organic acids are crucial to the flavor of the fruits. The average contents Brix degree and acidity were 4.6 and 0.50 g/100 g of citric acid, respectively (Hernandez *et al*, 2008). There is a continuous variation in the acidity of the fruit during its development and maturation, increasing with the growth of the fruit until it reaches its maximum with the development of coloration and diminishing with the advance of maturation.

Taste index

The taste index is calculated using the values of Brix degree and acidity, applying the equation performed by Navez *et al* (1999). Hernandez *et al* (2008) shows the mean values of these two parameters (Brix degree and acidity) according to cultivar, cultivation method and harvest period for the same group of tomatoes.

Tabe 4. Index of maturity and taste index in fruit of three tomato cultivars from organic and conventional production system

	Amati F1		**Robin F1**		**Elpida F1**	
	Organic	Convent.	Organic	Convent.	Organic	Convent.
Index of maturity	11.7a	10.3b	10.8b	10.3b	10.8b	9.6b
Taste index	1.00b	1.00b	0.98b	0.98b	1.10a	0.96b

The Elpida cultivar from organic production system had a mean value (1.1) of the taste index higher ($p < 0.05$) than those values determined for the organic Robin (0.98) and Amati (1.0) cultivars (table 4). No significant differences were found between the cultivars in the mean taste index obtained for conventional cultivated tomatoes. When using these data, the mean values of the taste index in all the tomatoes belonging to all the cultivars considered were higher than 0.85, which indicates that the tomato cultivars analyzed are tasty. If the value of the taste index is lower than 0.7, the tomato is considered as having little taste (Navez *et al*, 1999).

Another parameter related with the taste index is maturity index which is usually a better predictor of an acid's flavor impact than Brix degree or acidity alone. Acidity tends to decrease with the maturity of the fruits while the sugar content increases (Raffo *et al*, 2002).

We found significantly greater maturity index in organic ‘Amati’ fruit (11.7) and significantly lower maturity index in conventional ‘Elpida’ fruit (9.6) obtained for conventional and organically cultivated tomatoes. Maturity index in our study (in all cultivars in both production system) were higher than those found by maturity index reported by Hernandez *et al* (2007) was 9.4 and therefore, it can be deduced that the maturity levels of the analyzed tomatoes were adequate for consumption (Nielsen, 2003). This ratio can also be affected by climate, cultivar and horticultural practices (Nielsen, 2003). However, no significant differences were observed in the mean values of maturity between the tomato cultivars considered.

CONCLUSIONS

There are many factors such as cultivar, cultivation method and region of cultivation that influence the chemical composition of tomatoes. The cultivar is a more influential factor than cultivation methods in the differentiation of the tomato samples according to the chemical characteristics. The main factor influencing tomato mineral content was cultivar. ‘Elpida’ from organic production had greater concentration of K, Ca, Mg, B content and the best taste index.

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UTICAJ ORGANSKOG I KONVENCIJALNOG NAČINA PROIZVODNJE NA SADRŽAJ MINERALNIH MATERIJA I ČINIOCA UKUSA PLODA PARADAJZA

SAŽETAK

Tri hibrida paradajza (Robin-F1, F1-Amati i Elpida-F1) u plastenicima (Severoistočna Grčka) gajeno je na organskim i konvencionalnim sistemima proizvodnje. Razlike između metoda proizvodnje prisutne su u pogledu sistema zaštite i đubrenja. Korišćen je kozji stajnjak (30 t ha^{-1}) u organskom sistemu i 400 kg/ ha mineralnog slabo rastvorljivog đubriva NPK 12-12-17 +2 MgO + 8S + mikroelemenati u konvencionalnom sistemu gajenja. Cilj istraživanja bio je da se ispita da li ima razlika u sadržaju TSS, limunske kiseline i sadržaju minerala (K, Ca, Na, Mg, Fe, Zn, Mn, Cu) u paradajzu iz organske i konvencionalne proizvodnje. Razlike su više zavisne od sorti nego od proizvodnog sistema. "Elpida" je imala je najveći sadržaj mikroelemenata u odnosu na druga dva hibrida gajena pod istim uslovima. Našli smo znatno veće koncentracije P, K, Ca i Mg u organskom paradajzu, ali je u konvencionalno gajenom paradajzu prisutan veći sadržaj Zn, Fe i Cu. Metod gajenja ne utiče na koncentraciju B i Mn u plodu paradajza. "Elpida" je imala najveći sadržaj TSS i limunske kiseline (0.48%) u odnosu na ostale hibride pod istim uslovima proizvodnje. Takođe, indeks ukusa kod "Elpide" iz organske proizvodnje (1.10) je mnogo prijatniji, jer je odnos ukupno rastvorljivih suvih materija i ukupnih kiselina povoljniji onego kod paradajza iz konvencionalne proizvodnje.

Ključne riječi: paradajz, proizvodnja, organska, konvencionalna, mikroelementi.