

Full Length Research Paper

Effect of organic and conventional production practices on nutritional value and antioxidant activity of tomatoes

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The aim of this study was to compare fruit quality parameters in different tomato cultivars (Robin-F₁, Amati-F₁ and Elpida-F₁) derived from organic and conventional greenhouse production in North-Eastern Greece. Tomato fruit from conventional greenhouse production observed higher levels of TSS, sugars and vitamin C, while those grown organically contained substantial amounts of lycopene and carotenoids. The results obtained showed differences between cultivar and season of production. 'Elpida' cultivar had the highest content of TSS (5.08 %), sugar (4.10 mg 100⁻¹g fresh weight) and lycopene (37.5 mg kg⁻¹g fresh weight) of the three different varieties grown under same conditions. Also, the fruit flavor in organic production was much more pleasant because the ratio of total sugar and total acid more favorable than the tomatoes from conventional production. Organic tomatoes were perceived by some of the panelist to be *softer*, and were preferred because of their taste, flavor, texture and juiciness. Conventional tomatoes were however described as "*not as ripe*", "*dry*", and having "*less aroma*".

Key words: *Lycopersicum esculentum*, growing system, nutritional level, lycopene, taste.

INTRODUCTION

Organic agriculture is developing rapidly, and statistical information are now available from 154 countries of the world. In Switzerland for instance, organic vegetables account for 10% of all vegetables sold. In the US, organic fruit and vegetables account for 37% of all organic food sales (Wiler, 2010), while in Greece, now under organic production is 3.8% of total arable land. Tomato is the second most widely cultivated vegetable in the world after potato. Greece is at the 15th in the world and in Europe in third place with a total annual production of 1,338,600 MT.

Tomatoes are important not only because of the large amount consumed, but also because of their high health and nutritional contributions to humans. Most important, tomato consumption has been shown to reduce the risks

of cardiovascular disease and certain types of cancer, such as cancers of prostate, lung and stomach (Canene-Adams et al., 2005). The benefits of tomatoes and tomato products have been attributed mostly to the significant amount of lycopene contained, which constitutes 80 to 90% of the total carotenoid content present in tomatoes. Increased interest in organic tomato production is imposed by 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, conditions which all normally differ between the two systems (Magkos et al., 2003). Organic tomatoes achieved higher prices than conventional ones, because these products are often linked to sew up the environ-

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

Production system	Depth (cm)	pH		CaCO ₃ (%)	Humus (%)	N total (%)	P ₂ O ₅ (%)	K ₂ O (%)
		KCl	H ₂ O					
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

ment, better quality (taste, storage) and most people believe that they are healthier.

Moreover, research results on the effects of organic and conventional production on quality sometimes are 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 fruits and 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 aim of this study was to compare yield and quality parameters in different tomato cultivars derived from organic and conventional growing system.

MATERIALS AND METHODS

Experimental design and plant material

Three tomato variety (Robin-F₁, Amati-F₁ and Elpida-F₁) were tested in greenhouse production located in the Sapes, North-Eastern Greece (plastic tunnels 3.5 m high, covered by termolux 180μ) during 2008 to 2010, using two different growing systems; organic and conventional. Greenhouse technology and horticultural practices differed a little between conventional and organic greenhouse production. The main variations were concerned with pest control and fertility. In conventional cultivation, mineral fertilizers and chemical plant protection were applied (Table 1).

The differences between production systems were the fertilizer used (organic - goat manure; conventional- mineral fertilizer N₁₂:P₁₂:K₁₇, nitrophos blue special + 2MgO +8S +Trace elements – 400 kg/ha), the number of phytosanitary treatments (larger in organic system), the types of pesticide 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 on April 18th at a density (2.64

plant/m²).

Quality trail

At pink stage of ripening 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. Tomatoes samples were collected on June to August. All analyzes were carried out in Technological Faculty of Novi Sad and Analytical Laboratory of Biolab Epirus (Tzimas s. Bioepirus Ltd), Ioannina – Greece. Determination of total soluble solids (TSS) was measured by refractometer. The results were reported as °Brix at 20°C. The titrable acidity (TA) was measured with aliquots (5 ml) of juice that were titrated to pH 8.1 with 0.1 N NaOH (required to neutralize the acids of tomatoes in phenolphthalein presence) and the results expressed as citric acid percentages. Total and reducing sugars content was determined by the Luff-Shoorl's method, vitamin C content by Tillman's method and carotenoids (lycopene) by the liquid column chromatography method.

Sensory panel

The spring panel consisted of eleven panelists, three of which had participated in the fall descriptive analysis test. The recruitment criteria included that the panelists were (1) between the ages of 18 and 50, (2) not allergic to tomatoes, (3) consumers of fresh tomatoes at least twice a month, (4) able to pass a flavor acuity test and (5) available and willing to participate during training and testing sessions. During the training, panelists were presented with different kinds of commercially available tomatoes in order to acquaint them with different flavor attributes of tomatoes. Definitions of tomato flavor descriptors previously developed (Meilgaard et al., 1991; Civille and Lyon, 1996) were provided as a guide during terminology expansion. A final list of tomato flavor attributes definitions was retained after consensus by panel members. Panelists were trained using reference standards for sweet, sour, salty bitter and astringency (Meilgaard et al., 1991), plus fruity, earthy/musty, green/grassy and bite (Civille and Lyon, 1996). We also used the term tomato-like defined as “a general term that combines those characteristics commonly associated with tomato” using fresh cut tomatoes in training. The panel was calibrated to a maximum difference in response of ± 10 mm on the 150 mm scale for each descriptor.

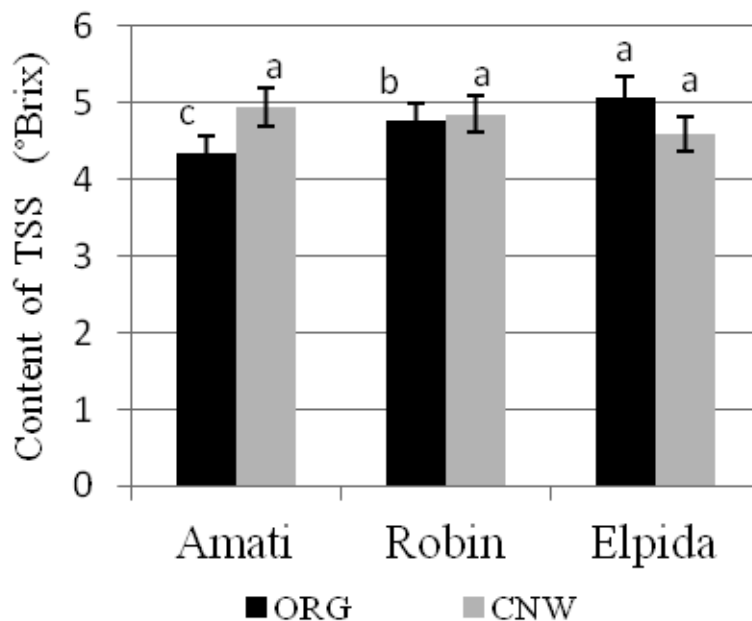


Figure 1. Content of total soluble solid (TSS) in organic and conventional tomato fruit. Different letters indicate significant differences at $P < 0.05$ (Tukey's test).

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

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. 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 Figures 1 to 6.

Organic tomatoes contained on average at all cultivars 4.73 °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 (Figure 1).

'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 °B) in comparison to the rest of examined tomato cultivars. Tomato fruit from conventional system, contained more total sugar, in average of all cultivars ($3.80 \text{ mg } 100^{-1}\text{g}$) in comparison with organic fruits ($3.75 \text{ mg } 100^{-1}\text{g}$), but

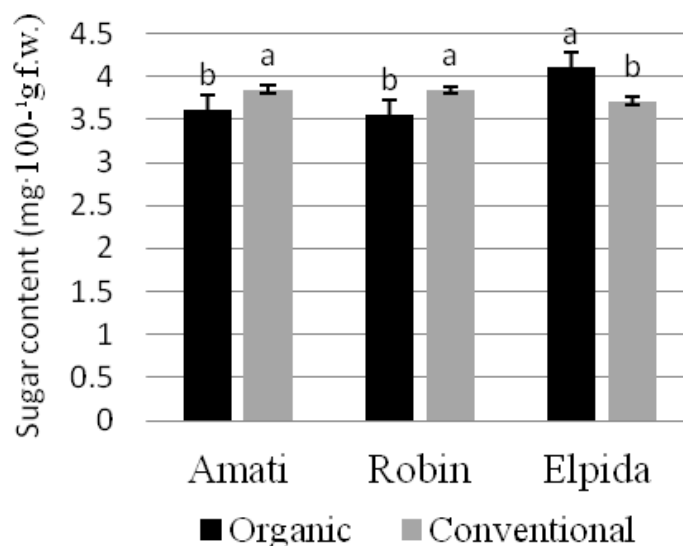
difference was not statistically significant. Conventional tomato fruit 'Amati' and 'Robin' contained more total sugars ($3.85 \text{ mg } 100^{-1}\text{g}$) in both periods of analysis in comparison with 'Elpida' cultivar ($3.71 \text{ mg } 100^{-1}\text{g}$). The tomatoes cultivars examined had different level of total sugars. 'Elpida' fruit from organic cultivation, contained more total sugars ($4.1 \text{ mg } 100^{-1}\text{g}$) in comparison to other cultivars examined (Figure 2). The concentration of sugars varied greatly as a function of the cultivar and cultivation conditions. According to Dorais et al. (2001), the concentration of sugars may vary from 1.66 to 3.99% and 3.05 to 4.65% of the fresh matter, as a function of the cultivar and cultivation conditions, respectively.

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 2). As with the sugars, the organic acids are crucial to the flavor of the fruits. 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.

It was observed that conventional tomatoes contained higher level of vitamin C in comparison with organic ones.

Table 2. Content of total acidity and vitamin C in fruit of three tomato cultivars from organic and conventional production system.

Parameter	Organic production (mg. 100 ⁻¹ g fresh weight)		Conventional production (mg. 100 ⁻¹ g fresh weight)	
	Total acidity	Vitamin C	Total acidity	Vitamin C
Amati	0.41	11.1	0.48	11.5
Robin	0.47	11.0	0.47	11.6
Elpida	0.47	12.1	0.49	12.5
Significance	*	n.s	n.s	n.s

**Figure 2.** Content of sugar in organic and conventional tomato fruit. Different letters indicate significant differences at $P < 0.05$ (Tukey's test).

The average content of vitamin C in all cultivars was 11.9 mg 100⁻¹g. Organic tomatoes contained statistically significant lowest level of vitamin C (11.4 mg 100⁻¹g). It tomatoes and significantly higher (12.5 mg 100⁻¹g) in conventional ones (Figure 3). The levels of some phenolic compounds are known to be higher in organic fruit. Plants create phenolic compounds for many reasons, but a major reason is to make plant tissues less attractive to herbivores, insects and other predators. Accordingly, it is important to sort out if higher levels of phenolic compounds affect the taste of organic fruits and vegetables when compared to conventionally grown produce (Benbrook, 2005). In addition, carbohydrates, organic acids and their interactions are important components of sweetness, sourness, and flavor intensity in tomatoes, thus acting as major determinants of tomato quality (Helyes et al., 2006). The results obtained showed that conventional tomatoes contained more total sugars and organic acids, although in the organic fruits, significantly more bioactive compounds such as vitamin C, β -carotene, flavonols and phenolic acids have been found. Only the content of lycopene was higher in the conventional fruits (Hallmann and Rembiałkowska, 2007).

was also found that 'Elpida' tomatoes contained more vitamin C in comparison to all tomato cultivars examined. Vitamin C in 'Elpida' fruit was 12.1 mg 100⁻¹g in organic. Agronomic and environmental factors are known to influence the development of tomato carotenoids. In this study, lycopene was identified as previously described (Abushita et al., 2000; Dumas et al., 2002; Binoy et al., 2004). Comparative trials investigating farming system effects on secondary metabolites should give additional consideration to the following: variety selection for maximizing lycopene production and minimizing genotype variation, sunlight availability and corresponding temperature/heat influences; planting and harvesting dates; irrigation practices and soil fertility management practices affecting plant nutrients found to influence carotenoid concentrations.

The average content of this pigment at the organic fruit was 2.92 mg.100⁻¹g, while for conventional tomatoes was 2.84 mg 100⁻¹g (Figure 4). Different tomato cultivars obtained different lycopene levels. At the same time, it should be noted that at the Elpida cultivar in organic produced contained more lycopene in fruit (3.75 mg 100⁻¹g) than at the all cultivars. Red color is initiated by

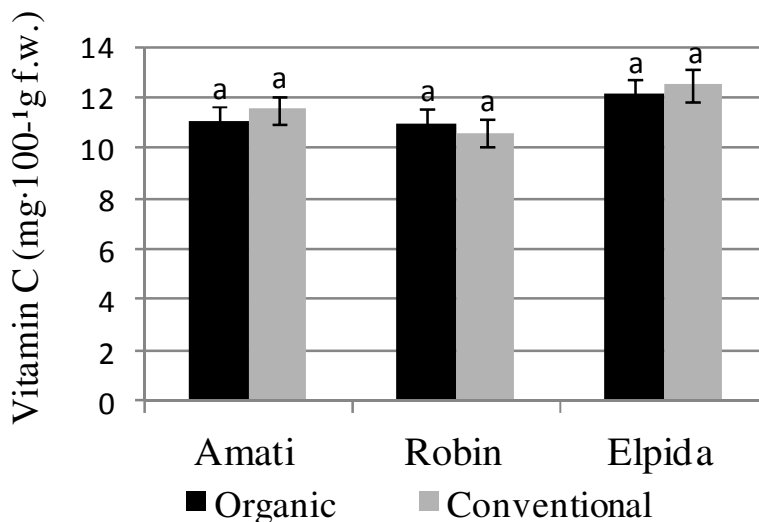


Figure 3. Content of vitamin C in organic and conventional tomato fruit.

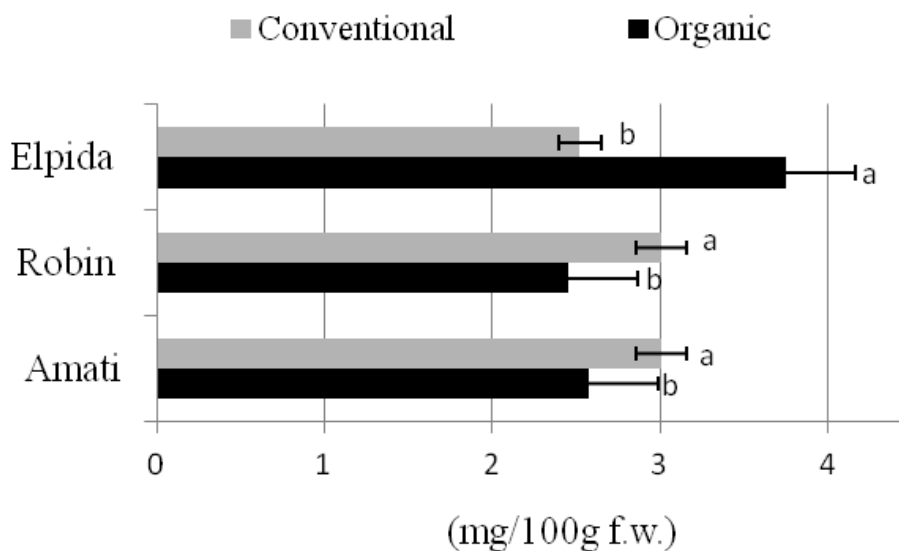


Figure 4. Content of lycopene in organic and conventional tomato fruit.

lycopene, which is the most abundant carotenoid in ripe tomatoes. Lycopene is the most abundant carotenoid present in red tomatoes, comprising up to 90% of the total carotenoids present. According to Brandt et al. (2003), significantly higher lycopene content was observed in tomato harvested in glasshouse-grown (83.0 mg kg⁻¹) than in field-grown (59.2 mg kg⁻¹), at different harvesting times. According to Farkas (1994), lycopene production is inhibited when environmental temperature is above 32°C. Lycopene content changed significantly during maturation and accumulated mainly in the deep red stage (Helyes et al., 2006). In some reports, lycopene has been seen as a good indicator for fruit maturity stage. Red colour and lycopene content of tomatoes could

however not always be correlated as reported by Dumas et al. (2002). Numerous investigations have been conducted to identify the factors influencing the contents of lycopene and vitamin C in tomatoes. The results demonstrate consistent differences in lycopene and vitamin C content between tomato cultivars and method of cultivation (Preedy and Watson, 2008). Differences in sunlight and temperature between the years might be a cause for the contradictory observations. Also, farm management skills combined with site-specific effects contributed to high lycopene levels, and the choice of variety significantly influenced the content of bioactive compounds, particularly ascorbic acid (Juroszek et al., 2009).

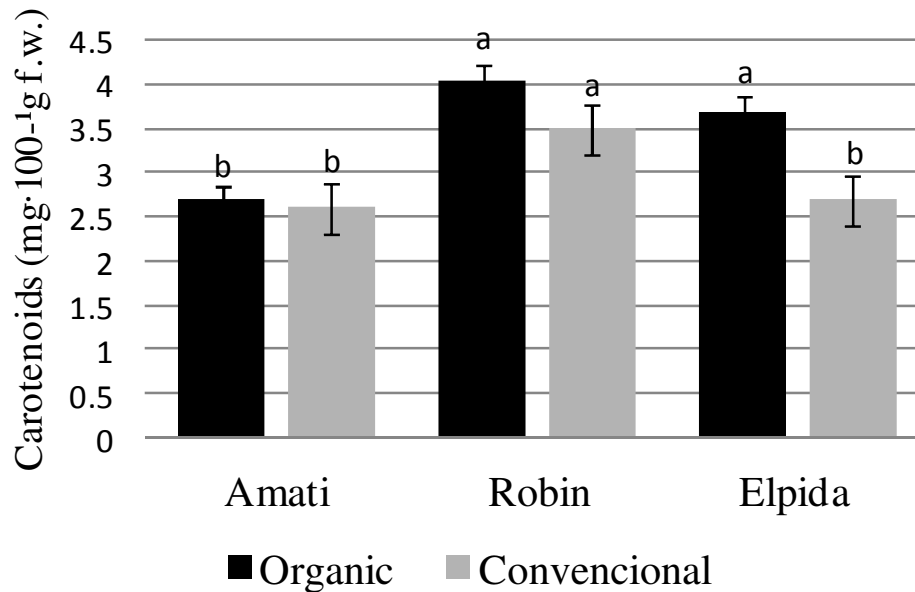


Figure 5. Content of carotenoids in organic and conventional tomato fruit.

Tomatoes from organic cultivation contained more carotenoids compared to conventional cultivation. The cultivar Amati however contained the lowest level of carotenoids in fruit in both cultivation systems, and these differences were statistically significant. Organic Robin tomatoes produced the highest level of carotenoids in fruit (4.03 mg 100⁻¹g) than at the all cultivars (Figure 5). Concerning carotene and lycopene contents in organic tomatoes, studies have reported different results including higher levels (Caris-Veyrat et al., 2004) or lower levels (Rossi et al., 2008) as compared with conventionally ones. No consistent effect of farming system on the content of bioactive antioxidant compounds (β -carotene, lycopene, vitamin C and total phenolics), as well as antioxidant activity (Juroszek et al., 2009) were also reported.

However, quality is more than this and can be defined as the sum of all characteristics that make a consumer satisfied with the product (Harker et al., 2003). Apart from functional and nutritional characteristics, quality can include aspects of production method, environment or ethics, as well as availability of and information about a product (Hauffman and Bruce, 2002). Sensory evaluation (duo-trio test with balanced reference) was conducted in 2008 to 2010 to determine whether consumers could perceive a difference between tomatoes grown conventionally or organically. Panelists could perceive a difference between conventional and organic tomatoes by smell or taste with high reliability. Organic tomatoes were perceived by some of the panelist to be *softer*, and were preferred because of their taste, flavor, texture and juiciness. Alternatively, conventional tomatoes were described as “*not as ripe*”, “*dry*”, and having “*less aroma*” (Figure 6). Very different patterns of correlation between

nonvolatile and volatile components emerged as perceived by panelists, depending on whether the nasal passage was blocked to evaluate taste descriptors. A composite of all data collected over the three seasons revealed the ‘sweet’ note is positively correlated with soluble solids, total sugars, and sucrose equivalents with partitioning (taste followed by aroma). No significant correlations were obtained without partitioning (aroma plus taste).

In previous studies, strong positive correlation has been observed between trained panel response of ‘sweetness’ and reducing sugar and total soluble solids content (Tandon et al., 2000). Both ‘tomato-like’ and ‘fruity’ were positively correlated to acidity and negatively correlated to soluble solids in aroma plus taste trials, but not in the taste followed by aroma trials. A possible explanation in the lack of correlations with many of these descriptors is that there was little difference between these treatments in the lines selected. It is clear that evaluating for taste plus aroma was more sensitive than evaluating for aroma plus taste. Untrained test panel preferred ‘Elpida’ over ‘Robin’ and ‘Amati’. It would however be impulsive to conclude that either production system is superior to the other with respect to healthy or nutritional composition. Further long-term studies at a commercial scale are therefore required to fully confirm these results.

Conclusion

Results show that organic system enhanced optimal production level but with higher cost of cultivation (certification procedures, higher cost per unit of fertilizer,

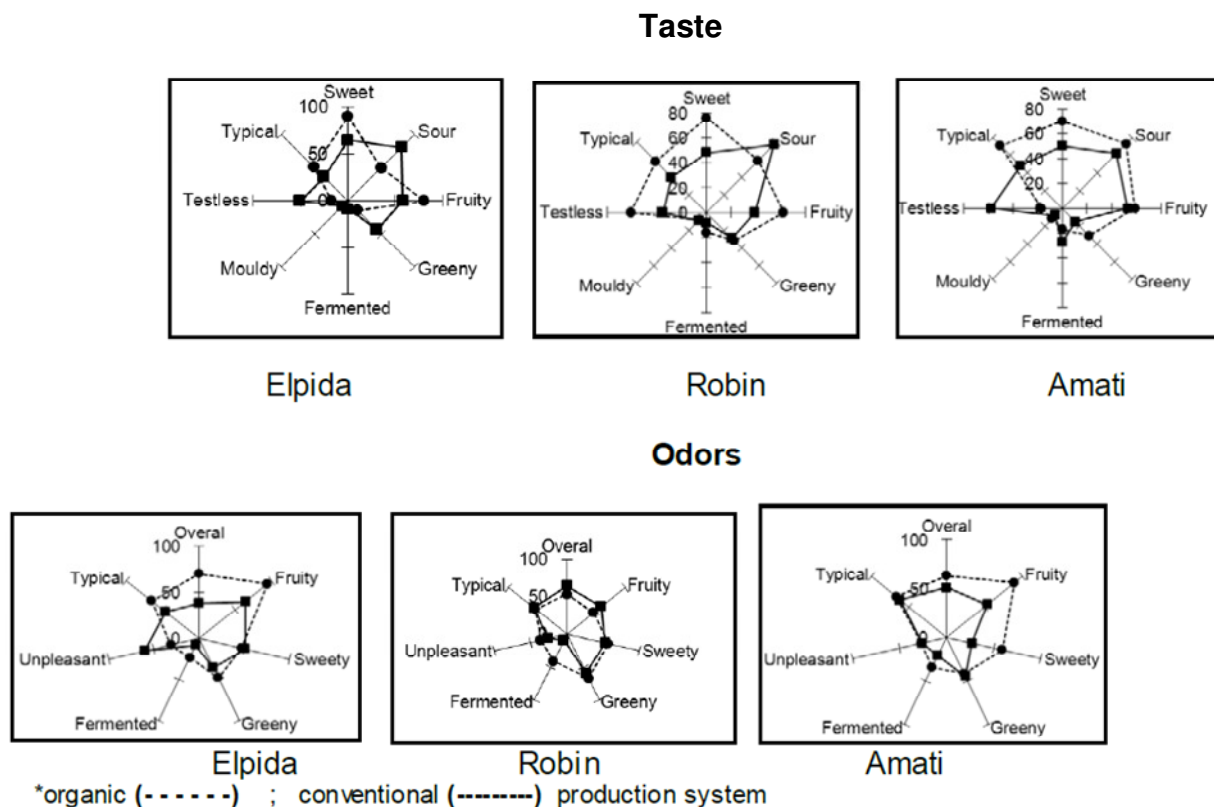


Figure 6. Tomato cultivars fruit odors and taste based on volatile and nonvolatile components and evaluated by trained panelists.

phytosanitary treatments applied etc.), compared with conventional farming. At the same time, organic tomatoes achieved a better price and guaranteed placement, so that the entire production was placed at 1.8 euro per kg. In general, we could not identify significant differences in quality parameters between tomatoes grown under conventional or organic farming systems.

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