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Organic *versus* conventional tomatoes: Influence on physicochemical parameters, bioactive compounds and sensorial attributes

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ABSTRACT

The effect of organic and conventional agricultural systems on the physicochemical parameters, bioactive compounds content, and sensorial attributes of tomatoes ("Redondo" cultivar) was studied. The influence on phytochemicals distribution among peel, pulp and seeds was also accessed. Organic tomatoes were richer in lycopene (+20%), vitamin C (+30%), total phenolics (+24%) and flavonoids (+21%) and had higher (+6%) *in vitro* antioxidant activity. In the conventional fruits, lycopene was mainly concentrated in the pulp, whereas in the organic ones, the peel and seeds contained high levels of bioactive compounds. Only the phenolic compounds had a similar distribution among the different fractions of both types of tomatoes. Furthermore, a sensorial analysis indicated that organic farming improved the gustative properties of this tomato cultivar.

1. Introduction

In the last century, new agricultural technologies and the massive use of chemical fertilizers, pesticides and herbicides provided an increased productivity at lower prices. The abuse of such substances resulted in pollution and ecosystems imbalance, and several studies reported a causal relationship between their use and the increase of cancers and congenital disorders in humans (Gold et al., 2001; Sanborn et al., 2007).

In the last two decades, organic agriculture has been increasing in order to meet the demand of a growing number of consumers who are willing to pay more for food produced by environmentally friendly practices and without pesticide residues (Didier and Lucie, 2008). One question remains without a clear answer, however, and that is whether the organic management system really improves or not the nutritional and organoleptic characteristics of the products.

Several studies have pointed out a better quality of organic foods compared to those from conventional production. For example, in a meta-analysis that included 41 studies, Worthington (2001) concluded that organic products have higher vitamin C, iron, magnesium, and phosphorus contents and lower nitrate values. Magkos et al. (2001) reviewed that organically grown leafy vegetables and potatoes have higher levels of vitamin C. In addition, higher phytochemical content and total antioxidant activity was observed in organic oranges (Tarozzi et al., 2006) and higher levels of phenolic compounds were found in organic apples (Petkovsek et al., 2010) compared to the counterparts produced in integrated systems. In a comparative study carried out with two types of tomato (standard and cherry), Hallmann (2012) also found that organic fruits contained higher contents of total sugars, vitamin C and total flavonoids. In turn, Cwalina-Ambroziak and Amarowicz (2012) stated that the use of biological and fungicidal control agents was negatively correlated with the levels of carotenoids and phenolic compounds in tomato fruits.

Nevertheless, the scientific opinion is far from being consensual, since several studies claim that there is no differences between the nutritional quality of organically and conventionally produced foodstuffs. For instance, Cardoso et al. (2011) concluded that there was no evidence of nutritional superiority of organically grown fruits (acerola, strawberries and persimmon) regarding vitamin C and carotenoids contents. Also, Gravel et al. (2010) found little differences in what concerns to taste and nutritional value of organic and conventionally grown tomatoes in greenhouses.

There is no question that the consumption of organic foods may reduce exposure to pesticide residues and antibiotic-resistant bacteria (Smith-Spangler et al., 2012), but given the number of contradictory results about the possible nutritional benefits, new data

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from controlled paired studies is essential to reach more conclusive results.

In this work, we sought to evaluate the effect of the cropping system (organic and conventional) on quality parameters (physicochemical properties, contents of bioactive compounds, antioxidant activity and organoleptic properties) of a Portuguese tomato cultivar (“Redondo”), which at present is produced almost exclusively by conventional means. As this tomato variety is widely appreciated by both home kitchen and industry of tomato-based products, the distribution of the nutrients among peel, pulp and seeds was also accessed.

2. Materials and methods

2.1. Chemicals and reagents

2,6-Dichloroindophenol sodium salt hydrate, meta-phosphoric acid, gallic acid, catechin, Folin–Ciocalteu's phenol reagent, DPPH· (2,2-diphenyl-1-picrylhydrazyl radical), sodium nitrite, aluminium chloride, n-hexane, methanol, and acetone were all obtained from Sigma–Aldrich (St. Louis, USA). Anhydrous sodium carbonate, sodium hydroxide and absolute ethanol were purchased from Merck (Darmstadt, Germany). Ultrapure water was treated in a Milli-Q water purification system (Millipore, Bedford, MA, USA) and used to prepare all aqueous solutions.

2.2. Samples and sample preparation

Sane and mature tomato fruits (*Lycopersicon esculentum* L.) from “Redondo” cultivar were harvested from two nearby greenhouses located in the littoral North of Portugal, Póvoa de Varzim (Latitude: 41.3826, Longitude: −8.7627941°22′57″ North, 8°45′46″ West) on September 2012. The cropping differences between the two greenhouses were only related with pest control and soil fertilization. According to the producer, in the conventional production, a synthetic fertilizer (Diamant®) was applied every week, while in organic production an organic fertilizer NPK (Agrimartin®) was incorporated into the soil, just before sowing. In the greenhouse used for conventional production, downy mildew and rottenness were prevented by spraying the plants every 15 days with a fungicide whose active ingredient is Folpet and with Rovral®. In the organic greenhouse, the producer used a 0.5% Bordeaux mixture (copper sulfate + slaked lime) as preventive fungicide. To control tomato caterpillars (*Helicoverpa armigera*) in the conventional cultivation system, the plants were sprayed with the insecticide KarateZeon® every 15 days. In the organic greenhouse, spinosad was used instead. *Tuta absoluta* was controlled in both greenhouses by means of pheromone traps.

The producer reported that the conventional production reached on average 1 t ha^{-1}, and ~10% of these fruits were rejected due to defects. The amount of tomatoes produced in the organic greenhouse reached ~0.55 t ha^{-1} and 20% were lost due to defects.

One hundred tomatoes were randomly harvested from each of the greenhouses (no more than three fruits per tomato plant) and immediately refrigerated at 4 °C. Six independent samples were analyzed for each type of treatment: whole fruits, fruits without peel and fruits without seeds. Each independent sample was prepared by homogenizing (MX-291-N, National, Osaka, Japan) four freshly collected washed fruits (whole, peeled or without seeds). Samples were then transferred into an amber air-tight container, flushed with nitrogen, and stored at −20 °C. All analyses were performed within two weeks after sample preparation.

2.3. Physicochemical analysis

Moisture was determined by drying 5.0 g of sample at 105 ± 1 °C, until constant weight (AOAC, 2000). Results were expressed in water percentage. The water activity (a_w) was measured using a Rotronic Hygropalm 9 VCD (Rotronic Instruments Ltd., Crawley, UK). A pH-meter (Microprocessor pH Bench-top HI 8417, Hanna Instruments) was used to determine pH values. Total soluble solids (TSS), expressed as °Brix, were determined using a NAR-3T refractometer (Atago Co. Ltd., Tokyo, Japan), adjusted and calibrated at 20 °C with distilled water. Color readings were performed with a Color Quest II Sphere colorimeter (Hunter Lab, Reston, VA). The a^* (red–green) and b^* (yellow–blue) values were used to calculate the hue angle value, $h° = \tan^{-1}(b^*/a^*)$. Analyses were performed in triplicate. Results are presented in Table 1.

2.4. Phytochemicals analysis

2.4.1. Ascorbic acid

Ascorbic acid content was determined, in triplicate, according to Vinha et al. (2014). Very briefly, sample aliquots were mixed with meta-phosphoric acid (0.1 g/L) for 45 min at room temperature and filtered. A filtrate aliquot was mixed with 2,6-dichloroindophenol, and spectrophotometric measurements were performed at 515 nm. Analyses were performed in triplicate and results were expressed as milligrams of ascorbic acid per 100 g of sample.

Table 1
Physicochemical parameters of the tomato fruits obtained from two agricultural management systems (conventional and organic).

Parameter	Fraction	Conventional	Organic
Moisture (%)	Whole	91.1 ± 0.2[b]	91.1 ± 0.4[a]
	Without peel	92.4 ± 0.5[a]	91.9 ± 0.9[a]
	Without seeds	91.0 ± 0.1[b]	91.4 ± 0.1[a*]
Water activity	Whole	0.96 ± 0.01[a]	0.96 ± 0.01[a]
	Without peel	0.96 ± 0.01[a]	0.96 ± 0.01[a]
	Without seeds	0.96 ± 0.01[a]	0.96 ± 0.01[a]
Acidity (pH)	Whole	4.46 ± 0.04[b]	4.38 ± 0.01[c*]
	Without peel	4.51 ± 0.01[a]	4.56 ± 0.01[a*]
	Without seeds	4.51 ± 0.01[a]	4.43 ± 0.01[b*]
Total soluble solids (TSS) (°Brix)	Whole	3.21 ± 0.01[c]	3.90 ± 0.01[a*]
	Without peel	3.29 ± 0.01[b]	3.89 ± 0.01[a*]
	Without seeds	3.36 ± 0.01[a]	3.40 ± 0.01[b*]
Hue angle (°h)	Whole	67.1 ± 3.9[a]	46.8 ± 0.7[b*]
	Without peel	70.2 ± 1.8[a]	53.4 ± 1.4[a*]
	Without seeds	53.5 ± 1.7[b]	38.5 ± 0.5[c*]

Results expressed as mean ± standard deviation obtained from triplicate measurements of six independent samples. Within each column, and for each individual parameter, different letters indicate significant differences ($p < 0.05$) between tomato fractions. The symbol “*” was used to indicate that the value of a parameter for a fraction of organic fruits is statistically different ($p < 0.05$) from that of the corresponding fraction on conventionally produced fruits.

2.4.2. Total phenolics

Total phenolics were determined, in triplicate, according to Vinha et al. (2014). Briefly, ~5 g of sample were extracted with 100 ml of methanol/water (80/20 v/v) for 1 h. After that, 500 μL of Folin–Ciocalteu reagent (1:10) were added to a filtrate aliquot (2 ml). The mixture was left 3 min at 25 °C before 0.2 ml of a saturated sodium carbonate solution being added. After standing at room temperature, absorbance readings were performed at 725 nm. Gallic acid was used as calibration standard.

As ascorbic acid also reacts with the Folin–Ciocalteu reagent, total phenolic contents were corrected for the ascorbic acid interference, according to Asami et al. (2003). The same methodology used for total phenolics quantification was performed for ascorbic acid standards and a calibration curve was obtained. The concentrations of ascorbic acid measured spectrophotometrically as described in Section 2.4.1 were then used to evaluate the contribution of the ascorbic acid to the absorbance detected in the total phenolics assay. Results were expressed as mg of gallic acid equivalents (GAE) per 100 g of sample.

2.4.3. Total flavonoids

Total flavonoids were estimated according to Alothman et al. (2009). Briefly, sample extracts (1 ml) were mixed with deionized water (4 ml) and 3 ml of $NaNO_2$ (5% w/v). The mixture was left to stand for 5 min before 0.3 ml of $AlCl_3$ (10%) were added, followed by 2 ml of 1.0 M NaOH after one more minute. The volume was completed to 10 ml with distilled water. The reaction mixture was mixed thoroughly for homogenization and absorbance was measured at 510 nm. Analyses were performed in triplicate. Catechin was used as calibration standard and results were expressed as mg of catechin equivalents (CE) per 100 g of sample.

2.4.4. Lycopene

Lycopene content was determined, in triplicate, according to Alda et al. (2009) with few modifications. Approximately 5 g of sample were added to a 50 ml mixture of hexane/acetone/ethanol (2:1:1, v/v/v) and incubated at ambient temperature (21 °C) for 30 min. The supernatant (hexane layer) absorbance was measured at 472 nm. Absolute hexane was used as blank. The amount of lycopene was estimated using the equation:

$$\text{Lycopene } (\mu g/g) = (A \times v \times 10^6)/(3450 \times W \times 100)$$

where v is the amount of hexane (ml), W the weight of sample (g), A the absorbance at 472 nm and 3450 the molar extinction coefficient.