Effect of peel and seed removal on the nutritional value and antioxidant activity of tomato (*Lycopersicon esculentum* L.) fruits

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A B S T R A C T

The effect of peel and seed removal, two commonly practiced procedures either at home or by the processing industry, on the physicochemical properties, bioactive compounds contents and antioxidant capacity of tomato fruits of four typical Portuguese cultivars (*cereja*, *chucha*, *rama* and *redondo*) were appraised. Both procedures caused significant nutritional and antioxidant activity losses in fruits of every cultivar. In general, peeling was more detrimental, since it caused a higher decrease in lycopene, β-carotene, ascorbic acid and phenolics contents (averages of 71%, 50%, 14%, and 32%, respectively) and significantly lowered the antioxidant capacity of the fruits (8% and 10%, using DPPH• and β-carotene linoleate model assays, correspondingly). Although seeds removal favored the increase of both color and sweetness, some bioactive compounds (11% of carotenoids and 24% of phenolics) as well as antioxidant capacity (5%) were loss. The studied cultivars were differently influenced by these procedures. The fruits most affected by peeling were those from *redondo* cultivar (−66% lycopene, −44% β-carotene, −26% ascorbic acid and −38% phenolics). Seeds removal, in turn, was more injurious for *cereja* tomatoes (−10% lycopene, −38% β-carotene, −25% ascorbic acid and −63% phenolics). Comparatively with the remaining ones, the *rama* fruits were less affected by the trimming procedures.

Keywords:
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1. Introduction

Tomatoes are universally recognized as a health promoting food. Their benefits are primarily associated with their rich composition in bioactive compounds such as lycopene, ascorbic acid, tocopherols, and polyphenols (Charanjeet, Binoy, Deepa, Balraj, & Kapoor, 2005; Klein & Kurilich, 2000; Peng, Zhang, & Ye, 2008; Prior & Cao, 2000; Wargovich, 2000). Several studies have shown that the concentration of these bioactive compounds in fresh tomatoes depends on factors such as cultivars (Valverde, González, Alonso, & Periago, 2013), soil and climate conditions (Garcia & Barrett, 2006; Kapoulas, Ilic, Durovka, Trajjkovic, & Milenkovic, 2011; Vinha, Soares, Herdeiro, & Machado, 2012), degree of ripening, and post-harvest storage conditions (Dumas, Dadomo, Lucca, & Grolier, 2003; Minoggio et al., 2003; Periago et al., 2009; Valverde, Periago, Provan, & Chesson, 2002; Vinha, Barreira, Castro, Costa, & Oliveira, 2013; Wold et al., 2004). Other factors expected to have a great influence on the nutritional value of tomato fruits are trimming and processing, the former due to an unequal distribution of nutrients in the fruit, and the latter because of thermal induced nutrient degradation.

Most tomatoes are, in fact, consumed in the form of pulp or cooked and in both instances the skin and the seeds are generally removed. It is commonplace to say that fruits should, whenever possible, be ingested unpeeled and this is not by chance, since the skin and seeds accumulate proteins, carbohydrates, lipids, and minerals, among other important phytochemicals (Knoblich, Anderson, & Latshaw, 2005).

Most of the available literature about the effect of processing on antioxidants from plant-based foods is related to operations such as canning, freezing, heating and blanching (Capanoglu, Beekwilder, Boyacioglu, De Vos, & Hall, 2010; Kaur, George, Deepa, Singh, & Kapoor, 2004; Klein & Kurilich, 2000; Shi & Le Maguer, 2000). Published data on the effect of trimming in their nutrient content

and antioxidant potential, namely the discard of the peel and seeds are, however, sparse and needed.

Several studies have already shown that the skin of some tomato fruits contains significantly higher levels of phenolics, flavonoids, lycopene, ascorbic acid and antioxidant activity than pulp and seed fractions (Sharma & Le Maguer, 1996; Shi & Le Maguer, 2000; Toor & Savage, 2005). These results led researchers to propose the peel enrichment of tomato-based products as a means to increase the nutritional value of tomato pastes and to enhance carotenoids intake (Reboul et al., 2005). Besides being itself a valuable source of nutrients, the skin also helps to preserve the nutritional value of the remaining parts of the fruit by acting as a protective organ. It maintains the physical integrity of tomato and prevents flesh deterioration, in particular, by avoiding a direct contact with air and, thus, preventing both dehydration and oxidation of sensitive chemical compounds. Indeed, Capanoglu et al. (2010) showed that the direct contact of the tomato pulp with oxygen can be very detrimental to ascorbic acid, lycopene and phenolic concentrations and this is why nitrogen-conditioned packaging for tomato derivatives is already in use. Moreover, the skin also prevents direct incidence of light on the pulp, another factor that has been linked to the deterioration of bioactive compounds (Lee & Chen, 2002; Peng et al., 2008).

Tomato seeds are edible and rich in bioactive compounds and minerals (González, Carmen Cid, & Lobo, 2011; Toor & Savage, 2005), nevertheless they are usually discarded specially in the preparation of tomato derivatives. Furthermore, recent studies showed that consumption of the natural gel found in tomato seeds can help to maintain a healthy blood circulation by preventing blood from clotting (O'Kennedy et al., 2006).

Hereupon, it is important to realize to what extent the peeling and seed removal in tomatoes affects their quality as food, especially regarding their antioxidant capacity. In the work here reported, we attempted to account for this in the case of fruits of four cultivars produced in Northern Portugal, namely, *cereja*, *chucha*, *rama* and *redondo*. For this purpose, the content of main tomato bioactive compounds, their physicochemical properties and antioxidant activity were determined, before and after skin or seeds removal.

2. Material and methods

2.1. Chemicals and reagents

2,6-Dichlorophenol (Tillmans reagent), sodium carbonate, oxalic acid, ethanol, *n*-hexane, acetone, β-carotene, butylated hydroxytoluene (BHT), citric acid, petroleum ether, chloroform, Tween 40 emulsifier, ascorbic acid and 2,2-diphenyl-1-picrylhydrazyl radical (DPPH•) were obtained from Sigma–Aldrich (St. Louis, MO, USA). Methanol, the Folin–Ciocalteu reagent, sodium hydroxide, linoleic acid, and gallic acid were purchased from Panreac Química S.L.U. (Barcelona, Spain). All aqueous solutions were prepared with Milli Q filtered water (resistivity >18 MΩ cm) (Millipore, Bedford, MA).

2.2. Samples

Fruits from four tomato cultivars (*cereja*, *chucha*, *rama* and *redondo*), produced conventionally, in the North of Portugal (Latitude: 41.3826, Longitude: −8.76279 41° 22′ 57″ North, 8° 45′ 46″ West) were studied. Approximately 10 kg of fruits from each cultivar, all in pink maturity stage, were randomly harvested from 10 different tomato plants located in the same plantation area. Freshly collected fruits were cleaned and used to prepare three distinct sample groups: whole fruits, fruits without peel and fruits without seeds. Samples were homogenized using a wet blender (MX-291-N, National, Osaka, Japan) for 1 min before being transferred into an air-tight container and stored at −20 °C.

2.3. Physicochemical characterization

Samples were analyzed for moisture content, water activity (a_w), total soluble solids (TSS), pH, maturity index (color) and titratable acidity (TA). Samples moisture was determined by the following gravimetric assay: 5 g of each fresh tomato sample in a porcelain capsule were placed in a stove (WTC binder Klasse 2.0, Tuttlingen, Germany) at (105 ± 1) °C, and regular weighting up to constant weight was undertaken. The a_w was measured using a Rotronic Hygropalm 9 VCD (Rotronic Instruments Ltd, Crawley, UK). TSS (°Brix) were quantified in the respective fruit purees using an Atago NAR-3T refractometer (Atago Co. Ltd., Tokyo, Japan). The pH value of the samples was measured using a pH-meter (Hanna Instruments, model 8417, Milano, Italy). Color readings were performed for each sample, after homogenization, using a Minolta Chromameter II Reflectancia CR-2000 (Minolta Limited, Milton Keynes, UK). The a^* (red-green) and b^* (yellow-blue) values were used to calculate the hue angle value, $h^* = \tan^{-1}(b^*/a^*)$. Acidity was measured by a direct titration method with 0.1 mol/L NaOH (AOAC, 2005). Briefly, a sample with ~10 g of crushed fruits was mixed in 90 ml of distilled water and stirred for 30 min. Titration was performed using phenolphthalein as indicator and results were expressed as mg of citric acid per 100 g of sample.

2.4. Determination of antioxidant compounds

2.4.1. Ascorbic acid assay

Ascorbic acid was determined according to the method of Klein and Perry (1982). Briefly, samples were mixed with metaphosphoric acid (0.1 g/L) for 45 min at room temperature and filtered through Whatman No. 4 filter paper. The filtrate (1 ml) was mixed with 2,6-dichlorophenolindophenol and ascorbic acid was quantified spectrophotometrically at 515 nm using a calibration curve obtained from measuring the absorbance of ascorbic acid standards. Results were expressed as milligrams of ascorbic acid per 100 g of fresh sample weight.

2.4.2. Total phenolics

The amount of total phenolic compounds was determined according to Jang et al. (2007). Each sample (~5 g) was subjected to extraction with 100 ml of methanol/water (80/20 v/v) for 1 h. Afterward, the solid was separated from the extract through vacuum filtration and a volume of 0.2 ml of each extract was added to 0.5 ml of Folin–Ciocalteu reagent (1:10). The mixture was left to rest for 3 min at 25 °C before adding 0.2 ml of saturated sodium carbonate solution. After standing at room temperature for 120 min, absorbance readings were performed at 725 nm using a UV–Vis spectrophotometer (Beckman DU-64 spectrophotometer, Beckman Instruments Inc., Fullerton, CA).

As ascorbic acid also reacts with the Folin–Ciocalteu reagent, total phenolic contents were corrected for the ascorbic acid interference, according to Asami, Hong, Barrett, and Mitchell (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 and subtracted from it. Total phenolics were then quantified by means of a calibration curve obtained from measuring the absorbance of gallic acid standards and expressed in mg per 100 g of fresh weight.

2.4.3. Carotenoids

β-carotene and lycopene were determined according to the method of Nagata and Yamashita (1992). Briefly, the pigments in ~1 g tomato samples were extracted with 20 ml of acetone/hexane (2:3, v/v), then the absorbance of the supernatants at 453, 505, 645, and 663 nm were measured by a BioTek Synergy HT microplate reader (GENS5). The contents of β-carotene and lycopene were calculated according to the following equations: β-carotene (mg/100 ml) = $0.216 \times A_{663} - 1.220 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453}$; lycopene (mg/100 ml) = $-0.0458 \times A_{663} + 0.204 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453}$, and further expressed in mg per 100 g of sample.

2.5. Antioxidant activity

The antioxidant activity of tomato samples was evaluated in methanolic and aqueous extracts which were obtained by mixing ~5 g of the homogenized tomato samples with 50 ml of methanol or 50 ml of water under constant stirring for 1 h. The methanolic and aqueous extracts thus obtained, after filtered, were stored under a nitrogen atmosphere at −20 °C. All experimental steps were carried out protected from light and under controlled temperature (25 °C).

2.5.1. DPPH radical-scavenging activity

The anti-radical ability of sample extracts was evaluated according to Brand-Williams, Cuvelier, and Berset (1995), with minor modifications. Tomato extracts (300 μl) were mixed with 2.7 ml of a methanolic DPPH• (6×10^{-5} mol/L). The mixture was shaken vigorously and absorbance readings at 515 nm were performed when a stable plateau was reached. The radical scavenging activity (RSA) was calculated as a percentage of DPPH• inhibition using the equation: % RSA = [(ADPPH − AS)/ADPPH] × 100, where AS represents the absorbance of the sample extract with DPPH• and ADPPH is the absorbance of the DPPH solution.

2.5.2. Antioxidant assay using the β-carotene linoleate model system

The antioxidant activity of tomato extracts was also evaluated by the β-carotene linoleate model system (Mi-Yae, Tae-Hun, & Nak-Ju, 2003). A solution of β-carotene was prepared by dissolving 2 mg in 10 ml of chloroform and 2 ml of this solution were pipetted into a 100 ml round-bottom flask. After the chloroform was removed under vacuum, 40 mg of linoleic acid, 400 mg of Tween 40 emulsifier, and 100 ml of aerated distilled water were added to it with vigorous shaking. Aliquots of this emulsion (5 ml) were then transferred into different test tubes containing 1 ml of tomato extract. As soon as the emulsion was added to each tube, the zero time absorbance was read at 470 nm. The tubes were placed at 50 °C in a water bath. Measurement of absorbance was continued until the color of β-carotene disappeared; a blank, devoid of β-carotene, was prepared for background subtraction. Antioxidant activity was calculated using the following equation: Antioxidant activity = (β-carotene content after 2 h of assay/initial β-carotene content) × 100.

2.6. Statistical analysis

A completely randomized design was used with three replications. Statistical analysis was performed using SPSS v. 20 (IBM Corp., Armonk, NY, USA). Data of all analysis were expressed as mean ± standard error. Analysis of Variance (ANOVA) followed by Tukey's HSD post-hoc test for multiple comparisons was used to assess the statistical differences among means ($p < 0.05$).

3. Results and discussion

3.1. Physicochemical parameters

Through the assessment of several physical and chemical parameters it is possible to infer the state of maturation and conservation, as well as the nutritional and commercial values of tomatoes. For example, tomato texture, taste and appearance are extremely dependent on the moisture content, whereas the a_w, which is a measure of the "free water", is an important variable in assessing the propensity for spoilage due to bacterial, mold or yeast contamination. The pH and TA are important criteria during fruit processing as they influence the shelf life of tomatoes and are used as reliable indicators of the overall quality of the fruit. Its flavor is also acid concentration dependent. TSS expressed as °Brix are related to the amount of sugars (mainly glucose and fructose) present in tomatoes and determine their sensory attributes, particularly taste, sweetness and acidity. Finally, the fruit color, besides being a parameter that, in conjunction with the firmness, is decisive in consumer purchase, is also an indicator of the amount of antioxidant pigments (especially lycopene) present in the fruit. The extent to which all these variables are affected by removal of peel and seeds, in the case of the four cultivars studied, is presented in Table 1.

Table 1
Physicochemical characterization of the different tomato fruit samples (1—whole fruit, 2—without peel, 3—without seeds) obtained from cultivars studied. pH value; hue angle (h^*); moisture (g/100 g) water activity (a_w); total soluble solids (TSS, °Brix); (TA) citric acid content (mg/100 g).

Cultivar	Physicochemical characterization					
	pH	h^*	Moisture	a_w	TSS	TA
$Cereja_1$	4.14 ± 0.01^c	60.1 ± 1.2^a	84.5 ± 1.1^a	0.99 ± 0.01^a	4.40 ± 0.11^a	319.9 ± 1.5^a
$Cereja_2$	4.26 ± 0.01^b	61.8 ± 1.6^a	84.7 ± 1.7^a	0.98 ± 0.01^a	4.44 ± 0.09^a	323.4 ± 1.9^a
$Cereja_3$	4.31 ± 0.01^a	57.5 ± 2.8^a	84.9 ± 1.5^a	0.98 ± 0.01^a	4.42 ± 0.04^a	168.4 ± 0.6^b
$Chucha_1$	4.44 ± 0.01^c	40.7 ± 0.9^b	89.7 ± 1.6^a	0.98 ± 0.01^a	4.05 ± 0.06^b	236.9 ± 0.2^a
$Chucha_2$	4.57 ± 0.01^b	53.1 ± 0.6^a	89.6 ± 0.6^a	0.98 ± 0.01^a	4.25 ± 0.03^a	216.8 ± 0.5^b
$Chucha_3$	4.60 ± 0.01^a	38.6 ± 0.7^c	90.2 ± 0.4^a	0.98 ± 0.01^a	4.21 ± 0.03^a	140.9 ± 1.2^c
$Rama_1$	4.45 ± 0.01^b	53.5 ± 2.2^b	84.2 ± 3.3^{ab}	0.98 ± 0.01^a	4.37 ± 0.09^a	248.6 ± 0.6^b
$Rama_2$	4.29 ± 0.01^c	58.4 ± 0.9^a	82.9 ± 0.9^b	0.98 ± 0.01^a	4.43 ± 0.06^a	293.0 ± 0.5^a
$Rama_3$	4.69 ± 0.01^a	49.8 ± 1.5^c	85.0 ± 0.4^a	0.98 ± 0.01^a	4.38 ± 0.03^a	189.4 ± 0.6^c
$Redondo_1$	4.43 ± 0.01^b	51.7 ± 1.5^b	84.1 ± 6.4^a	0.97 ± 0.04^a	4.48 ± 0.07^{ab}	305.6 ± 0.7^b
$Redondo_2$	4.35 ± 0.01^c	59.2 ± 0.7^a	84.7 ± 1.5^a	0.97 ± 0.04^a	4.59 ± 0.05^a	334.2 ± 1.1^a
$Redondo_3$	4.60 ± 0.01^a	49.8 ± 0.4^c	87.0 ± 1.0^a	0.97 ± 0.03^a	4.52 ± 0.01^b	137.3 ± 0.6^c

*Values expressed as mean ± standard deviation obtained from 3 measurements per replicate. For each cultivar, different lowercase superscript letters indicate significant differences ($p < 0.05$) caused by peel or seeds removal.

Removing the skin and seeds had practically no effect on the moisture and a_w of the samples, affecting more the pH, color, TSS and TA. The effect of peeling on pH is not straightforward, since in the case of *rama* and *redondo* cultivars there is a significant decrease ($p < 0.05$), while for *cereja* and *chucha* a slight increase ($p < 0.05$) occurred. In a general way, peeling resulted in a statistically significant ($p < 0.05$) increase in hue angle which may be explained by the fact that the skin is rich in pigment compounds, namely carotenoids.

Except for *chucha* cultivar, in which an increase was observed, no statistical differences in TSS contents ($p > 0.05$) were found between peeled and unpeeled. For that cultivar, peeling also caused a decrease of TA, while for the remaining samples this parameter was maintained (for *cereja* tomatoes) or increased (for *rama* and *redondo* cultivars). In the last case, a higher concentration of organic acids (mainly citric and malic) in the pulp fraction could be behind this occurrence.

Seed removal entailed an increase in the pH of the tomatoes that is statistically significant irrespective of the cultivar. Presumably, this derives from the fact that the seeds have high contents of organic acids and tannins. The removal of the seeds was also accompanied by a significant decrease ($p < 0.05$) in both hue angle and TA which is directly related to the loss of yellowish seeds rich in the referred compounds.

Summarizing, in percentual values, the physicochemical parameters most affected by the removal of the skin were the color (hue angle: +3% *cereja*, +30% *chucha*, +9% *rama* and +15% *redondo*) and TA (+1% *cereja*, −9% *chucha*, +18% *rama* and +9% *redondo*). Seed removal also affected color (−4% *cereja*, −5% *chucha*, −7% *rama* and −4% *redondo*) but, above all, reduced the TA (−47% *cereja*, −41% *chucha*, −24% *rama* and −55% *redondo*). Peeled tomatoes contain a lower amount of pigments and that seedless tomatoes are less acidic per unit of mass.

3.2. Bioactive compounds

Bioactive compounds (extranutritional constituents typically occurring in small amounts in foods) have been intensively studied regarding their health effects (Kris-Etherton et al., 2002). The most important bioactive compound associated with tomatoes is lycopene, a potent antioxidant carotenoid thought to protect against prostate and other cancers by inhibiting tumor cell growth (Giovannucci, 1999). Nevertheless, the tomato also contains significant levels of other bioactive compounds such as phenolics (whose antioxidant properties are thought to protect against thrombosis and tumorigenesis), vitamin C (a powerful antioxidant with an essential role against oxidative stress) and β-carotene or provitamin A (which has an important role in vision, wound healing, increase body resistance to toxins and cancer prevention (Soobrattee, Neergheen, Luximon-Ramma, Aruomab, & Bahorun, 2005; Tanaka, Shnimizu, & Moriwaki, 2012).

Table 2 shows the effect of the trimming procedures on the levels of the aforementioned compounds for the tomato cultivars studied. The impact of the studied procedures was not the same in all bioactive compounds or for all the tomato varieties. Elimination of the skin had more effect on the content of lycopene (−80% in the case of *rama* fruits, −73% for *cereja*, −66% for *redondo*, and −65% for *chucha* fruits), followed by that of β-carotene, total phenolics and ascorbic acid, while removing the seeds altered the value of the bioactive compounds in the following sequence: phenolics > β-carotene > lycopene > ascorbic acid. Regarding the bioactive compounds analysed, peeling affected most the fruits of both *chucha* and *redondo* cultivars, whereas taking the seeds away was more detrimental for *cereja* fruits and, in a lower extent, *chucha* ones. These results are consistent with the fact that the fruit epidermis and the seeds are rich in carotenoids, phenolic compounds and ascorbic acid, as previously reported by Toor and Savage (2005) for fruits from Excell, Tradiro and Flavourine cultivars grown under hydroponic conditions in commercial greenhouses. Also, Chandra and Ramalingam (2011) conducted a study with Indian cultivars reporting a very uneven distribution of bioactive compounds among the skin, pulp and seed fractions, with the skin containing the highest level of antioxidant compounds. Globally, the results presented in Table 2 show that, whenever skin and seeds were removed, a significant ($p < 0.05$) loss of bioactive compounds occurred. It was noticed, in general, that peeling was more detrimental than the removal of the seeds.

Table 2
Concentration of bioactive compounds present in different tomato fruit samples (1—whole fruit, 2—without peel, 3—without seeds). (AA) Ascorbic acid (mg/100 g); (TP) Total phenolic content (mgGAE/100 g). (βC) β-carotene content (mg/100 g); (LC) Lycopene content (mg/100 g).

Cultivar	Bioactive compounds contents			
	AA	TP	βC	LC
$Cereja_1$	62.7 ± 0.9^b	61.6 ± 2.6^a	1.6 ± 0.1^a	15.8 ± 0.1^a
$Cereja_2$	73.6 ± 0.9^a	22.8 ± 5.7^b	0.9 ± 0.1^b	4.3 ± 0.1^c
$Cereja_3$	47.2 ± 0.4^c	22.6 ± 1.5^b	1.0 ± 0.1^b	14.2 ± 0.2^b
$Chucha_1$	$39.8 \pm 0.2\underline{a}$	79.3 ± 6.1^a	0.7 ± 0.1^a	14.2 ± 0.1^a
$Chucha_2$	31.8 ± 0.1^c	56.6 ± 3.9^b	0.3 ± 0.1^c	5.0 ± 0.1^c
$Chucha_3$	34.9 ± 0.3^b	61.1 ± 4.5^b	0.7 ± 0.1^a	11.9 ± 0.1^b
$Rama_1$	44.2 ± 0.3^a	54.2 ± 0.5^b	0.9 ± 0.1^a	$10.7 \pm 0.5\underline{a}$
$Rama_2$	36.7 ± 0.5^c	55.6 ± 1.0^a	0.4 ± 0.1^c	2.1 ± 0.1^b
$Rama_3$	40.3 ± 0.3^b	55.5 ± 0.6^a	0.8 ± 0.1^b	$10.3 \pm 0.6\underline{a}$
$Redondo_1$	37.7 ± 0.1^b	66.9 ± 5.2^a	0.9 ± 0.1^a	8.8 ± 0.1^a
$Redondo_2$	27.9 ± 0.7^c	41.7 ± 3.9^b	0.5 ± 0.1^b	3.0 ± 0.1^c
$Redondo_3$	49.9 ± 0.2^a	58.2 ± 1.7^a	0.9 ± 0.1^a	7.7 ± 0.2^b

*Values expressed as mean ± standard deviation obtained from 3 measurements per replicate. For each cultivar, different lowercase superscripts indicate statistical significant differences ($p < 0.05$) caused by removal of peel or seeds.

3.3. Antioxidant capacity

The antioxidant capacity represents the ability to inhibit the process of oxidation. It is a very desirable property of foods since oxidation plays a crucial role in the pathogenesis of several human diseases and aging. Tomatoes are recognized as a food with high antioxidant properties due to the presence of several natural antioxidants with complementary mechanisms of action (e.g. lycopene, phenolic compounds, ascorbic acid) (George, Kaur, Khurdiya, & Kapoor, 2004; Toor & Savage, 2005; Valverde et al., 2013, 2002). The need to account for chemically diversified substances motivated the development of different methods to evaluate the antioxidant capacity of foods.

In this study, two methods were used to evaluate the antioxidant capacity of the extracts: the DPPH• (2,2-diphenyl-1-picrylhydrazyl radical) inhibition assay and the β-carotene linoleate model system. The DPPH• assay a rapid, simple and inexpensive way to evaluate the antioxidant activity of samples by testing their ability to act as free radical scavengers or hydrogen donors. The basis of this method is that the antioxidants react with the stable free radical DPPH• and convert it to 2,2-diphenyl-1-picrylhydrazine with color change (from purple to yellow). The absorbance decrease at 515 nm indicates the scavenging potential of the sample (Prior, Wu, & Schaich, 2005; Tabart, Kevers, Pincenmail, Defraigne, & Dommes, 2009).

Besides the DPPH• radical-scavenging activity, the antioxidant capacity of the samples was also evaluated by the β-carotene linoleate model system. In this model system, the linoleic acid free radical formed upon the abstraction of a hydrogen atom from one of its diallylic methylene groups attacks the highly unsaturated β-carotene molecules. Consequently, β-carotene is oxidized and broken down in part, and the system loses its chromophore and

Table 3
Antioxidant activity (A.A.) of methanolic and aqueous extracts obtained from 1—whole, 2—peeled and 3—seedless tomato fruits on 2,2-diphenyl-1-picrylhydrazyl radical (DPPH) and by the β-carotene linoleate model system (βCL).

Cultivar	A. A. DPPH (%)		A. A. βCL (%)	
	Methanolic	Aqueous	Methanolic	Aqueous ext
$Cereja_1$	39.9 ± 0.7^{c}	23.5 ± 1.4^{a}	36.3 ± 0.2^{a}	29.3 ± 2.0^{a}
$Cereja_2$	41.2 ± 2.0^{a}	22.0 ± 1.3^{b}	29.6 ± 0.3^{b}	27.8 ± 0.3^{b}
$Cereja_3$	40.3 ± 1.2^{b}	21.9 ± 1.3^{c}	30.5 ± 2.4^{b}	29.0 ± 0.2^{a}
$Chucha_1$	73.3 ± 2.7^{a}	62.3 ± 1.5^{a}	42.0 ± 0.6^{a}	40.9 ± 0.9^{a}
$Chucha_2$	56.5 ± 2.8^{c}	54.4 ± 0.7^{c}	39.5 ± 0.2^{b}	37.3 ± 2.2^{b}
$Chucha_3$	68.0 ± 2.2^{b}	58.2 ± 1.0^{b}	40.2 ± 0.1^{b}	40.0 ± 2.6^{a}
$Rama_1$	59.6 ± 0.8^{a}	37.1 ± 0.4^{a}	36.7 ± 0.4^{a}	34.2 ± 0.4^{a}
$Rama_2$	55.0 ± 11.5^{c}	37.1 ± 0.8^{a}	32.3 ± 0.6^{b}	30.6 ± 0.9^{b}
$Rama_3$	58.9 ± 1.4^{b}	34.2 ± 0.6^{b}	34.7 ± 1.8^{a}	32.1 ± 1.9^{a}
$Redondo_1$	60.3 ± 0.8^{a}	56.1 ± 1.3^{a}	39.2 ± 0.2^{a}	38.6 ± 0.1^{a}
$Redondo_2$	59.1 ± 0.2^{c}	48.8 ± 0.8^{c}	37.7 ± 0.2^{b}	33.6 ± 0.9^{b}
$Redondo_3$	60.0 ± 0.3^{b}	52.0 ± 1.6^{b}	38.1 ± 0.3^{a}	39.1 ± 1.1^{a}

*Values expressed as mean ± standard deviation obtained from 3 measurements per replicate. For each cultivar, different lowercase superscripts indicate statistical significant differences ($p < 0.05$) caused by removal of peel or seeds.

characteristic orange color that can be monitored spectrophotometrically (Jayaprakasha, Singh, & Sakariah, 2001). This decolorization can be decreased or prevented by antioxidants that donate hydrogen atoms to quench radicals (Prior et al., 2005).

It has already been documented that the efficiency of each assay highly depends on the way samples are prepared, inter alia, the polarity of the solvents used. According to this, assays were performed for both aqueous and methanolic extracts obtained from tomato samples. The results are presented in Table 3.

The removal of the skin and seeds reduces the ability of the tomato material to capture DPPH•. Nevertheless, this reduction is not identical for all cultivars. For example, it was not perceptible for the methanolic extracts obtained from the *cereja* tomatoes nor for the aqueous extracts of the *rama* cultivar after removal of the skin. On the other hand, losses of nearly 23% and 7% were measured after removing the skin or seeds of the *chucha* tomatoes. Peeling affects the antioxidant capacity to a greater extent than seed removal, a trend that is also corroborated by the β-carotene linoleate test. These results are consistent with those reported in literature concerning studies with other fruits (Ju & Howard, 2003; Luque-Rodriguez, Luque de Castro, & Perez-Juan, 2007; Palma, Pineiro, & Barroso, 2001; Pineiro, Palma, & Barroso, 2006) and can be interpreted taking into account the effect of skin and seed removal on the concentration of the bioactive compounds previously discussed. Indeed, the fruits which loose more bioactive compounds due to the skin or seeds removal (*chucha*) were also those with the major loss in terms of antioxidant capacity. The results also revealed that the methanolic extracts have more antioxidant activity than the correspondent aqueous ones (Table 3). According to the solubility of the bioactive compounds analysed in this study, the main antioxidant compound present in the aqueous extracts is expected to be ascorbic acid (highly polar), while methanolic extracts should contain mainly phenolic compounds. In turn, lycopene and β-carotene are hydrophobic molecules with no affinity to water and very low affinity to methanol, therefore they should only be present in methanolic extracts in minimal amounts.

4. Conclusions

The results of this study demonstrate that despite possible positive effects like color enhancement, increased sweetness and reduced astringency, significant amounts of the compounds that make the tomato so beneficial are lost simply by removing its skin or seeds. The removal of the skin is more detrimental, since it can represent a loss of 80% lycopene (*rama*), 57% of β-carotene (*chucha*), 26% of ascorbic acid (*redondo*) and 63% of phenolic compounds (*cereja*). Removing the seeds has greater impact, percentually, in the amount of total phenolics reaching 63% loss in the case of *cereja* cultivar. The antioxidant capacity of the studied cultivars is proportional to its content of bioactive compounds; hence it is more diminished by skin removal. It should be noted that the studied tomato cultivars are not affected to the same extent. The varieties that, overall, display the greatest losses in its phytochemicals levels and antioxidant capacity as a consequence of skin removal are *chucha* and *redondo* while *cereja* is the one more affected by seed removal. The cultivar that globally seems to be more unaffected by these trimming procedures is *rama*.

The results of this research substantiate the idea that in order to benefit from the full nutritional and antioxidant potential that tomato can provide one should eat the whole fruit. When this is not feasible, the skin and seeds, given their nutritional value, should be harnessed as byproducts.

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