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Quality and safety evaluation of new tomato cultivars

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PAPER

Abstract

This paper is aimed to provide a quality and safety assessment of new cherry tomato cultivars (*Solanum Lycopersicum var. cerasiforme*): *Bamano, Dulcemiel*, and *Sugarland.* Eight biogenic amines, total phenolics, total carotenoids, lycopene, and antioxidant activity (2,2-diphenyl-1-picrylhydrazyl [DPPH] and 2,2-azino-bis (3-ethylbenzo thiazoline-6-sulfonic acid) diammonium salt [ABTS] assays) were determined. Comparison with control cultivars demonstrated lower pH values, and total contents of biogenic amines and antioxidant compounds while having higher soluble solid concentration. Moreover, multivariate statistical analyses (principal component analysis and cluster analysis) were applied to the results. Different results allowed for a successful differentiation of new cultivars. Therefore, the chosen compounds resulted in suitable markers for quality and safety assessment of tomatoes.

Keywords: antioxidants, biogenic amines, carotenoids, food safety and quality, phenolics, tomato

Introduction

Tomato (*Solanum Lycopersicum*) is an annual plant whose berries are used widely, either processed or raw, for food and beverage. Tomato plants are native to South America, and their cultivation in the Mediterranean countries dates back to the 17th century (Peralta and Spooner, 2014). Italy is the first tomato-producing country in Europe and one of the top 10 producers in the world (Food and Agriculture Organization Corporate Statistical Database [FAOSTAT], 2019). Italy also tops the list for global export of processed tomatoes ahead of China (Istituto Servizi Mercato Agricolo Alimentare, 2017). In Italy, tomatoes are cultivated especially in the central and southern regions, where small-size tomato varieties are much appreciated (Masetti *et al.*, 2014; Carillo *et al.*, 2019). Tomato is of great value in the global vegetable consumption, and recently, there has been an increase in the spread of new small-size tomato cultivars. Small-size tomatoes are preferred for fresh consumption than regular-size tomatoes, and consumers choose the same for their organoleptic proprieties (Liu *et al.*, 2019). Tomato is one of the most studied crops, and their genetic improvement is constant. The breeding programs led to the offspring of new varieties that can meet the industry and/or consumer preferences.

Moreover, through new cultivars, disease resistance is achieved. Recently, new hybrid cultivars of tomatoes named *Bamano*, *Dulcemiel*, and *Sugarland* have been introduced in Central Italy. These cultivars are trying to expand the fresh agronomic market with products characterized by unique organoleptic and nutritional properties. Usually, seed companies evaluate prime properties (e.g., size, color, sugars, etc.) under different stress and environmental conditions, followed by researchers' early characterization (Ingallina *et al.*, 2020c). However, in order to valorize the final product, quality and safety assessment is highly recommended. Quality assessment is necessary to determine molecular markers, typical of

a sample, that can establish the sample's origin or the good state of storage (Giuggioli *et al.*, 2016). Antioxidant compounds are usually used to evaluate food quality (Armenta and de la Guardia, 2016). Phenolic compounds, secondary metabolites of many plants, are ubiquitous in the vegetable domain and they are one of the most extensively studied groups of natural compounds. Their dietary intake is highly recommended, and they have anti-microbial and anti-carcinogenic effects (Coyago-Cruz *et al.*, 2018). These compounds have already been detected in good quantity in commercial tomatoes, especially in small-size varieties (Selli *et al.*, 2014). Tomatoes have a significant antioxidant activity afforded by phenolic compounds and antioxidants such as carotenoids, lycopene, and vitamins (Szabo *et al.*, 2018). Total phenolic content, 2,2-diphenyl-1-picrylhydrazyl (DPPH), and 2,2-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) diammonium salt (ABTS) assays are established as quick and robust tools for characterizing antioxidants in the fractions of hydrophilic tomatoes. They are used widely in an explorative and preliminary assessment of vegetables and fruits (Fanasca *et al.*, 2006; Preti *et al.*, 2017). Besides, to characterize the antioxidants present in the lipophilic fraction, such as carotenoids (including lycopene), Ultraviolet–Visible spectroscopy (UV-Vis) methods are used generally (Ingallina et *al.*, 2020a).

Other metabolites present in small amounts in food are often used as markers of food safety. Among these compounds, biogenic amines (BAs) are widely used as food safety markers because of their presence in food and their effect on the human body. BAs are the result of the decarboxylation of amino acids, but their presence in food can also be related to spoilage. In addition, BAs can induce several negative physiological reactions, and the investigation of their levels in food is important for consumers' health and the formulation of diets (Kalač, 2014). Some BAs, such as histamine (HIS) and tyramine (TYR), pose potential risks to human health, that is, 'scombroid food poisoning' and 'cheese crisis' (Al Bulushi *et al.*, 2009). However, not all BAs are dangerous for human health. For example, serotonin (SER) plays an essential role to regulate mood, sleep, body temperature, sexuality, and appetite in the central nervous system (Hano *et al.*, 2017). Therefore, its presence in food could be an exciting feature. Notwithstanding that presence of BAs is regulated in some foods and drinks, some authors have suggested BAs to be food quality markers (Silla Santos, 1996).

In this work, a quality and safety assessment of three new tomato cultivars is proposed. At first, soluble solid concentration (SSC) and pH were determined to evaluate physicochemical characteristics of the tomato cultivars. Thereafter, an evaluation of antioxidants present in hydrophilic and lipophilic fractions was carried out. The hydrophilic antioxidant fraction was tested by *in vitro* antioxidant activity through scavenging of DPPH- and ABTS-free radicals and total phenolic content by the Folin–Ciocâlteu method. Total contents of carotenoids and lycopene were analyzed in lipophilic fraction by UV-Vis methods.

Moreover, the profile of eight BAs was evaluated in tomato samples by high-performance liquid chromatography with fluorescence detection (HPLC-FD) after dansyl chloride derivatization. The BAs studied were spermine (SPM), spermidine (SPD), putrescine (PUT), and cadaverine (CAD) for polyamines, whereas β-phenylethylamine (β-PEA), HIS, SER, and TYR were studied for monoamines. The above-mentioned analyses were also conducted on samples from two traditional cultivars of tomatoes used for fresh market and canning industry.

Finally, a multivariate statistical analysis (principal component analysis [PCA] and cluster analysis [CA]) was conducted on the bioactive compound profiles of tomatoes to highlight natural differentiation of samples coming from the new cultivars.

Materials and methods

Materials

Methanol (CH_3OH), n-Hexane (C_6H_{14}), water (HPLC grade), acetonitrile (HPLC grade), Folin–Ciocâlteu reagent ($H_3[P(W_3O_{10})_4]/H_3[P(Mo_3O_{10})_4]$), ABTS, DPPH, potassium persulfate, sodium bicarbonate ($NaHCO_3$), gallic acid ($C_7H_6O_5$), perchloric acid ($HClO_4$), sodium hydroxide (NaOH), sodium carbonate (Na_2CO_3), and ammonium hydroxide (NH_4OH) were purchased from Sigma Aldrich Chemical Co. The eight BAs—HIS, SER, SPM, SPD, PUT, β-PEA, CAD, and TYR—were supplied by Supelco (Bellefonte, PA, USA) as well as the derivatizing agent, dansyl chloride, and the internal standard, 1,7-diaminoheptane (IS).

Sampling

Tomato samples were supplied by eight different farmers with similar pedo-climatic conditions, located in the south of Lazio region (Italy), which were harvested in 2016. Tomato seeds (Bamano and Dulcemiel) were supplied by Syngenta, Basel, Switzerland and Rijk Zwaan, De Lier, The Netherlands (Sugarland). Two samplings per cultivar were prepared for each farm. A total of 48 samples were collected (Bamano, n =16; Dulcemiel, n = 16; and Sugarland, n = 16). Moreover, other 11 samples were collected from selected cultivars for fresh market and canning industry. After acquisition, samples were

Table 1. Physical characteristics of new tomato cultivars.

Cultivar	Color	Size	Fruit weight	Picture
Bamano	Bright orange	Elongated shape (2.5 ± 0.5 × 4.5 ± 0.5 cm)	11 ± 1 g	
Dulcemiel	Green with honey shades	Round shape (2.5 ± 0.5 × 3.5 ± 0.5 cm)	15 ± 1 g	
Sugarland	Deep shiny red	Round shape (1.5 ± 0.5 × 2.5 ± 0.5 cm)	12 ± 1 g	

homogenized by an Ultra-Turrax system and stored at –18°C. The physical characteristics of each cultivar are reported in Table 1.

Physicochemical parameters

The SSC was determined with a portable refractometer (RS PRO; Milan, Italy) at 20°C and expressed as °Brix. The pH was measured with a pH-meter (Hach Company; Loveland, CO, USA).

Determination of Biogenic Amines

Extraction

Biogenic amines were extracted according to a previously optimized tomato products method (Chiacchierini *et al.*, 2006). About 8 g of sample, previously added with 0.1 mL of IS (100 mg/L), was extracted with 10 mL of 0.6 M $HClO_4$, homogenized for 3 min, and centrifuged at 2,700 *g* for 10 min. The supernatant was filtered through a 0.20-µm membrane Millipore filter and collected in a flask. The residue was added with 10 mL of 0.6 M $HClO_4$, mixed, and again centrifuged for 10 min. Then the second extract was filtered and added to the first one. The final volume was adjusted to 25 mL with 0.6 M $HClO_4$.

Derivatization

An aliquot of 1 mL of the final extract was derivatized according to procedures reported by Ingallina *et al.* (2020b). About 200 µL of 2M NaOH, 300 µL of saturated $NaHCO_3$ solution, and 2 mL of dansyl chloride solution (10 mg/mL in acetone) were added in a tube. After shaking, the samples were left in dark for 60 min at 45°C. About 100 µL of 25% NH_4OH was added to stop the derivatizing reaction. The final volume was adjusted to 5 mL by adding acetonitrile. The dansylated extract was filtered using 0.22-µm filter (Polypro Acrodisc, Pall Gelman Laboratory, USA) and injected into the HPLC system (Ingallina *et al.*, 2020b).

Chromatographic setup

Chromatographic separation was achieved by a system consisting of a LC-10 ATVP binary HPLC pump, a Supelcosil LC-18 column (Supelco, 5-µm particle size, 150 × 2.1-mm I.D.) equipped with a Supelguard LC-18 guard column (Supelco Inc., Bellefonte, PA, USA), and an RF-10AXL fluorescence detector (Shimadzu, Kyoto, Japan). The injector was fitted with a 20-µL loop. The chromatographic data were collected and processed using Class-VP software (Shimadzu). The analysis was conducted as described in previous work. Fluorescence detection was set at 320 nm for excitation and 523 nm for emission. Identification of the BAs was based on their retention time and adding of standards. The quantification was performed using the internal standard calibration method by linear regression analysis ($R^2 > 0.995$).

Extraction of hydrophilic antioxidant compounds

Sample extractions for antioxidant activity and total phenolic content were prepared from 2 g of tomatoes in 20 mL of methanol. Samples were homogenized in an Ultra-Turrax for 3 min and centrifuged at 2,400 *g* for 5 min (Fratoddi *et al.*, 2018).

Determination of total phenolic content (Folin–Ciocâlteu)

Total Phenolic Content (TPC) was determined using the Folin–Ciocâlteu method (Fratoddi *et al.*, 2018), modified for tomatoes as follows: 1 mL of methanolic extract was

added to 0.25 mL of Folin–Ciocâlteu reagent and 0.5 mL of Na_2CO_3 water solution (7.5% w/v) in a 10-mL volumetric flask. The final volume was reached with purified water. Spectrophotometric analysis was performed at λ = 750 nm after 45 min of incubation in dark at room temperature. TPC was expressed as milligrams of gallic acid equivalent (GAE) per kg. The final results were obtained through a calibration curve ranging from 15 to 500 mg/L (R^2 = 0.9925).

Determination of antioxidant activity

The DPPH and ABTS assays were based on the same mode of action, and they are common *in vitro* antioxidant tests (Tonolo *et al.*, 2019). The disappearance of radical was determined by measuring absorbance at 515 nm (DPPH) and 734 nm (ABTS) as described previously (Preti *et al.* 2017); the absorbance was measured in 1-cm path length cuvettes, using a UV-Vis spectrophotometer (Jenway, Stone, UK).

Results were expressed as inhibition rate and were calculated based on Equation 1:

$$I\% = \frac{A_0 - A_f}{A_0} \times 100, \quad (1)$$

where A_0 is the radical cation's initial absorbance, and A_f is the absorbance after the addition of sample extract.

Lipophilic antioxidant extraction

Briefly, 7 mL of ethanol:hexane mixture (4:3 v:v) was added to 0.1-g homogenized sample in a glass tube (protected from light). The lycopene extraction was conducted by agitating the mixture for 1 h (darkness) at 200 rpm. Thereafter, 1 mL of distilled water was added to the mixture and stirred by inversion. The hexane fraction was then collected in an amber vial.

Total carotenoids

The total carotenoid content was determined at 449 nm (Ingallina *et al.*, 2020a). The results were compared with a standard solution of β-carotene in n-hexane, and the quantification of total carotenoids was achieved by the linear regression (r^2 = 0.9962) and expressed as milligram of β-carotene (mg BCE).

Lycopene determination

The lycopene determination was performed by measuring the hexane phase absorbance at 472 nm in a spectrophotometer. The lycopene content was calculated with the Lambert–Beer Law as described in Equation 2:

$$\text{Lycopene (mg / kg)} = \frac{Abs \times MW \times 2.7}{w \times E}, \quad (2)$$

where *Abs* is the absorbance reading, *MW* is the molecular weight, 2.7 refers to the volume (in mL) of the hexane phase, *w* is the sample weight, and *E* is the molar extinction coefficient of lycopene in hexane (185.3 mM/cm). Results were expressed as mg/kg of lycopene (fresh weight, FW) (Antolinos *et al.*, 2020).

Statistical analysis

All the experiments were conducted in triplicate and expressed as mean ± standard deviation. T-test, correlations, and chemometric data analyses (PCA and CA) were performed with JMP software (ver. 15.2, SAS Institute, Cary, NC, USA).

Results and discussion

Physicochemical properties

The presence of phytochemicals in tomatoes, such as carotenoids and phenolic compounds, mineral salts, and organic and fatty acids content is closely related to their health-promoting properties. Therefore, these are used in quality and safety assessment. These compounds are biosynthesized and accumulated in fruits, and their content is influenced by environmental factors, cultural practices, and genetic aspects, such as different cultivars (Antolinos *et al.*, 2020). In this respect, pH and SSC were evaluated in the examined samples, and the results are reported in Figure 1. The new cultivar samples had significantly lower pH values ($P < 0.01$) compared to control cultivars, even if the difference was 8–10%. These results suggest a possible use of specific consumers satisfaction related to their organoleptic and sensorial features. Moreover, the highest SSC was found for Sugarland cultivar, followed by Bamano and Dulcemiel. The resulting SSC values of new cultivars were statistically different from that of the control, indicating greater soluble solid compounds.

Biogenic amines

The evaluation of BAs in fresh vegetables has been recently explored in literature, tomatoes included (Sánchez-Pérez *et al.*, 2018). According to Sánchez-Pérez *et al.* (2018), the BAs found in tomatoes were HIS (n.d.–22 mg/kg FW); TYR (n.d.–6.38 mg/kg FW); PUT (5.3–35.5 mg/kg FW), and CAD (n.d.–2.33 mg/kg FW).

In this study, contents of eight BAs were determined in three new cultivars of cherry tomatoes; their profiles are shown in Figure 2.

The chromatograms exhibited different trends for the three cultivars. An appreciable peak resolution was achieved (Palomino-Vasco *et al.*, 2019; Ramos *et al.*,

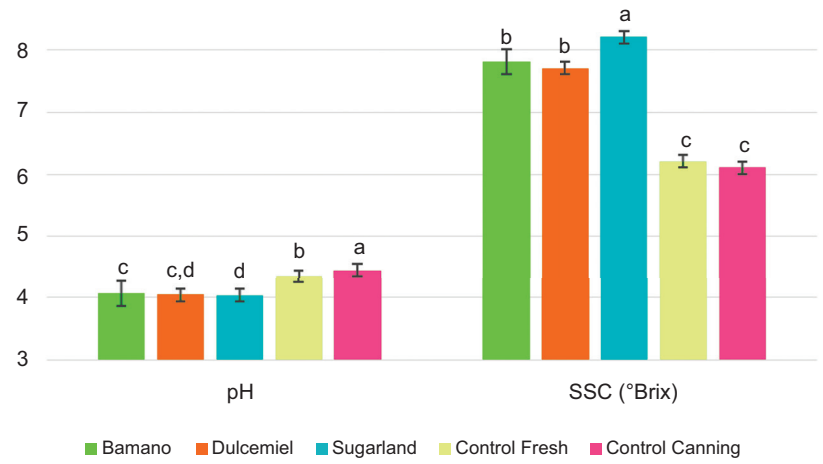

Figure 1. Determination of physicochemical properties of different tomato cultivars: pH and soluble solid concentration (SSC) (°Brix). Samples not connected by the same letter are significantly different.

2020). The quantification of BAs in new cultivars and control tomatoes is summarized in Table 2. Table 2 also describes the T-test results (α = 0.95) of each variable for the five categories of the sample analyzed.

Among new cultivars, the highest total BA contents in tomatoes was determined in Sugarland (275.2 ± 11.10 mg/kg), followed by Dulcemiel (201.01 ± 1.71 mg/kg) and Bamano (137.36 ± 1.98 mg/kg). These contents were comparable with the control canning cultivar, in spite of the fact that the fresh control had a higher total BA values.

The amount of HIS, PUT, and CAD of the new cultivars (<LOQ: 0.57 mg/kg, 0.16–5.75 mg/kg, and 1.15–2.41 mg/kg, respectively) was in agreement with results from literature, while TYR was below the limit of quantification for all the samples. Compared with the control cultivars, the HIS values were comparable with that of the canning cultivar and were lower than that of the fresh cultivar

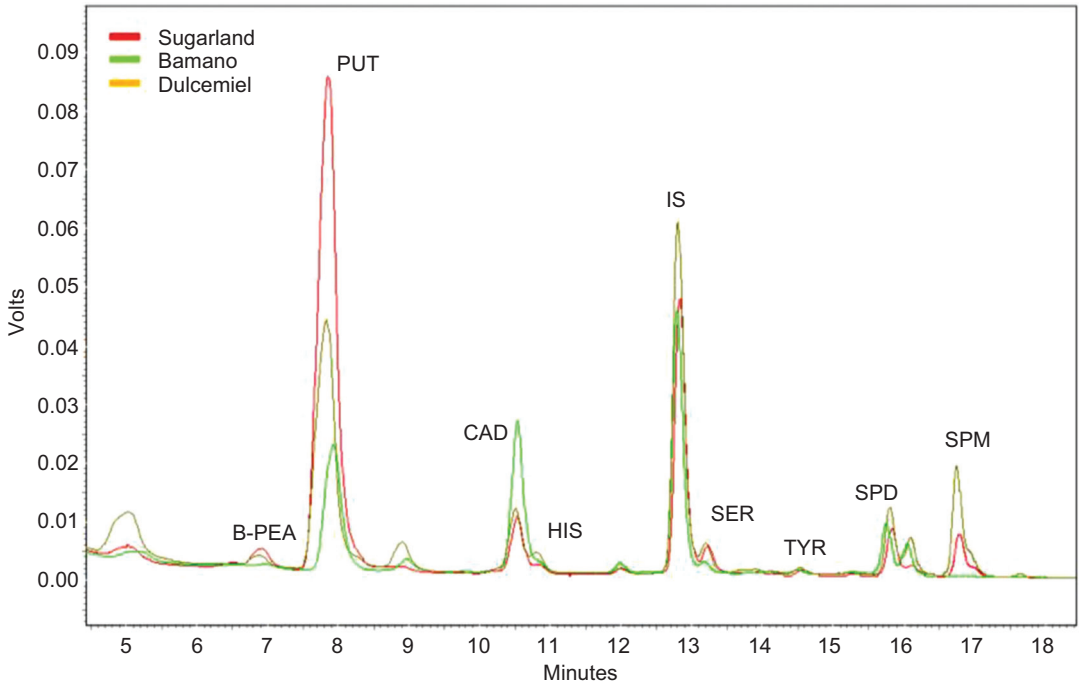

Figure 2. Chromatographic profiles of biogenic amines determined in tomato samples: Sugarland (red trace), Bamano (green trace), and Dulcemiel (dark yellow trace). β-PEA: β-phenylethylamine; PUT: putrescine; CAD: cadaverine; HIS: histamine; IS: internal standard; SER: serotonin; TYR: tyramine; SPD: spermidine; and SPM: spermine.

Table 2. Quantitative results of biogenic amines in tomato samples (mg/kg). Samples not connected by the same letter are significantly different.

	Bamano	Dulcemiel	Sugarland	Control fresh	Control canning
β-PEA	$1.16^{b} \pm 0.05$	$0.17^{c} \pm 0.001$	$0.17^{c} \pm 0.01$	$1.47^{a} \pm 0.12$	$1.13^{b} \pm 0.10$
PUT	$0.16^{c} \pm 0.01$	$0.56^{c} \pm 0.03$	$5.75^{b} \pm 0.14$	$11.17^{a} \pm 4.17$	$4.98^{b} \pm 0.21$
CAD	$2.41^{a} \pm 0.09$	$1.15^{b} \pm 0.01$	$1.22^{b} \pm 0.02$	$0.94^{c} \pm 0.15$	$0.70^{d} \pm 0.03$
HIS	$<LOQ^{c}$	$0.57^{a,b} \pm 0.02$	$0.33^{b,c} \pm 0.01$	$1.01^{a} \pm 0.41$	$0.10^{b,c} \pm 0.06$
SER	$132.47^{d} \pm 2.05$	$197.27^{c} \pm 1.71$	$266.87^{b} \pm 11.16$	$379.51^{a} \pm 4.06$	$146.81^{c,d} \pm 8.67$
TYR	$<LOQ^{c}$	$<LOQ^{c}$	$<LOQ^{c}$	$1.29^{a} \pm 0.09$	$0.67^{b} \pm 0.08$
SPD	$0.29^{b} \pm 0.01$	$0.37^{b} \pm 0.02$	$0.33^{b} \pm 0.01$	$8.32^{a} \pm 0.40$	$8.32^{a} \pm 0.85$
SPM	$0.87^{b} \pm 0.04$	$0.91^{b} \pm 0.06$	$0.53^{c} \pm 0.02$	$0.80^{b,c} \pm 0.03$	$1.16^{a} \pm 0.47$
Total BAs	$137.36^{d} \pm 1.98$	$201.01^{c} \pm 1.71$	$275.2^{b} \pm 11.10$	$404.53^{a} \pm 9.45$	$164.67^{c,d} \pm 10.53$

β-PEA: β-phenylethylamine; PUT: putrescine; CAD: cadaverine; HIS: histamine; SER: serotonin; TYR: tyramine; SPD: spermidine; SPM: spermine; total BAs: total biogenic amines; LOQ: limit of quantification.

(1.01 ± 0.41 mg/kg). Besides, in the control cultivar, TYR was also observed (0.67 – 1.29 mg/kg). It is essential to underline BAs' shallow levels such as HIS and TYR, frequently reported as dangerous in the human diet (Linares *et al.*, 2016). Although, the HIS and TYR contents were not dangerous, a lower concentration in new cultivars allowed products with lesser contamination at the processing stage.

Polyamines, such as SPD and SPM, play a role in increasing shelf life of tomatoes. The gene expression related to SPD and SPM would reduce the post-harvest senescence and decay (Handa and Mattoo, 2010; Nambeesan *et al.*, 2010). Thereafter, the low amount of SPD (0.29–0.37 mg/kg) and SPM (0.53–0.91 mg/kg) found in all new cultivars could be a desirable feature. They could be related to a natural over expression of some metabolic pathways in these cherry tomato varieties, contributing to the elongation of shelf life. Also, the lowest concentrations in new cultivars, compared to the control, suggest these tomato cultivars' eligibility in the supply chain.

Finally, an interesting remark should be made about the SER content. The SER content was the major contributor to the total contents of BAs established in the samples, starting from 132.47 ± 2.05 mg/kg (96%) for Bamano to 197.27 ± 1.71 mg/kg (98%) for Dulcemiel and 266.87 ± 11.16 mg/kg (97%) for Sugarland. These results were in agreement with already published results (Riga *et al.*, 2016). A similar trend in SER content was also found in control cultivars (90–93%), although in slightly lower proportions. However, the excellent SER content in tomato fruits is related to its several physiological functions in plants (e.g., growth regulator, protection against pathogens, etc.). In plants, SER is produced from tryptophan, and demonstrates some positive effects on the human body. Daily assumption of SER-rich vegetable varieties has demonstrated, *inter alia*, useful anti-obesity and anxiety control effects (Islam *et al.*, 2016). Moreover, it has been proved that the SER content tends to decrease in processed tomato products. Therefore, tomato cultivars relatively rich in SER could be of interest for the tomato industry (Hano *et al.*, 2017).

Antioxidants evaluation

Nowadays, several features, such as being rich in nutrients or having physiological benefits, are searched in foods. Among these, antioxidant compounds are the most interesting nutrients for human health, and are considerably present in fruits and vegetables (Dudonné *et al.*, 2009). Moreover, these compounds are widely used to evaluate food quality. The hydrophilic and lipophilic fractions were examined to evaluate antioxidants in new tomato cultivars.

TPC assay was chosen to quantify phenolics' content in hydrophilic fraction, essential components of antioxidant compounds in tomatoes (Fanasca *et al.*, 2006). The antioxidant activity was also tested by two different *in vitro* anti-radical assays—ABTS and DPPH (Campestrini *et al.*, 2019). Moreover, these two radicals are sensitive to different types of antioxidants. Consequently, their combined use consented to an effective evaluation of antioxidant activity.

The results and significant differences are shown in Table 3. For TPC, Sugarland had the highest results with 303.15 ± 21.62 mg GAE/kg, followed by Dulcemiel and Bamano (256.39 ± 6.63 and 242.18 ± 6.6 mg GAE/kg, respectively). TPC results were in accordance with previously reported tomato results, especially for cherry tomatoes (Raffo *et al.*, 2002; Riga *et al.*, 2016).

Table 3. Quantitative results of evaluation of antioxidants in tomato samples. Samples not connected by the same letter are significantly different.

	Bamano	Dulcemiel	Sugarland	Control fresh	Control canning
TPC (mg GAE/kg)	242.18^{d}± 6.60	256.39^{d}± 6.63	303.15^{c} ± 21.62	369.98^{b} ± 12.37	458.97^{a} ± 3.11
DPPH (I%)	88.61^{b}± 3.42	93.38^{a}± 3.47	91.25^{a} ± 1.36	93.46^{a} ± 1.34	92.04^{a} ± 0.74
ABTS (I%)	60.34^{b}± 1.92	26.63^{d} ± 1.54	32.50^{c}± 2.49	96.82^{a} ± 0.29	98.64^{a} ± 0.38
TCC (mg BCE/kg)	40.12^{c} ± 2.69	33.12^{d} ± 0.99	54.12^{b} ± 1.36	142.00^{a} ± 5.05	143.17^{a} ± 4.99
Lycopene (mg/kg)	29.25^{c} ± 7.48	12.12^{d} ± 1.25	48.88^{b} ± 2.95	127.80^{a} ± 1.79	128.50 ^{a} ± 1.38

TPC: total phenolic content; TCC: total carotenoids content; DPPH: 2,2-diphenyl-1-picrylhydrazyl; ABTS: diammonium salt; GAE: gallic acid equivalent.

The trend of TPC results agreed with DPPH radical scavenging assay for antioxidant activity, proving a high radical inhibition by the three cultivars. The lowest result was achieved by Bamano cultivar (88.61, I%). A similar result was reported by Lu *et al.* (2020), who established that TPC values could be positively correlated with the DPPH values (Lu *et al.*, 2020). However, Bamano variety had demonstrated the highest ABTS scavenging activity results (60.34, I%), followed by Sugarland (32.50, I%) and Dulcemiel variety (26.63, I%). In Bamano samples, these results could be explained by a more significant presence of other chemical compounds with antioxidant activity not included in the phenolic compounds, such as vitamin C or anthocyanins (Pataro *et al.*, 2015; Marengo *et al.*, 2017).

Total carotenoids and lycopene contents were evaluated in the lipophilic fraction of antioxidants by UV-Vis methods. Among new cultivars, Sugarland had the highest content of carotenoids (54.12 ± 1.36 mg BCE/kg) and lycopene (48.88 ± 2.95 mg/kg), followed by Bamano (40.12 ± 2.69 mg BCE/kg, 29.25 ± 7.48 mg/kg) and Dulcemiel (33.12 ± 0.99 mg BCE/kg, 12.12 ± 1.25 mg/kg). These values of compounds in new tomato cultivars were compared with the literature data (D'Evoli *et al.*, 2013). It is also appropriate to highlight that lycopene is the major carotenoid in cherry tomatoes, representing 40–90% of the total carotenoid contents in new cultivars.

The values obtained were significantly lower than that of control, except for DPPH assay results for Sugarland and Dulcemiel cultivars.

Multivariate analysis

Different profiles of bioactive compounds found in tomatoes had suggested the hypothesis that some of the compounds detected for quality and safety assessment could also be typical of a cultivar (Uarrota *et al.*, 2014). Therefore, their presence as a potential authenticity marker of the tomato variety was investigated (Bajoub *et al.*, 2016). For this purpose, PCA and CA were used to explore data matrices in order to highlight a natural grouping among samples (Marengo *et al.*, 2017). Autoscaling pretreatment was conducted in the data matrix composed of experimental results (Nur Azira *et al.*, 2014). The PCA results are reported in Figure 3: Sugarland is represented by circles, Bamano by squares, Dulcemiel by crosses, control fresh by stars, and control canning by triangles. In PCA, the first two principal components (PC1 and PC2) accounted for 82.9% of the total variability (Liu *et al.*, 2013). In the scores plot, all cultivars were clearly separated (Šamec *et al.*, 2016). New cultivars are located in the left part of the diagram, Sugarland and Dulcemiel in the upper part, while Bamano in the lower one. Control cultivars were located on the right, fresh cultivar samples on the top, and the canning ones on the lower part. As highlighted by the scores plot, PC1 differentiated new cultivars (Sugarland, Bamano, and Dulcemiel) from the control. This PC was highly influenced by physicochemical properties (pH and SSC), carotenoids (including lycopene), phenolic compounds, and SPD and TYR for BAs. Separation among each cultivar was enabled by PC2, whereby BAs (SER, BAI, HIS, and β-PEA) and DPPH anti-radical assays were the major contributors.

To characterize new cultivars, PCA was recalculated by excluding control cultivars. The scores and loadings' plot of this analysis are given in Figure 4.

The loadings' plot pointed out for Dulcemiel samples was positively correlated with DPPH, SPD, and HIS variables. It is clear in Tables 2 and 3 that Dulcemiel cultivar had the highest content in these compounds. Sugarland demonstrated a positive correlation with SER, BAI, PUT, TPC, SSC, total carotenoids, and lycopene. Moreover, Sugarland had a high negative correlation with SPM. Samples of the Bamano cultivar were positively correlated with CAD, β-PEA, pH, and ABTS content. Therefore,

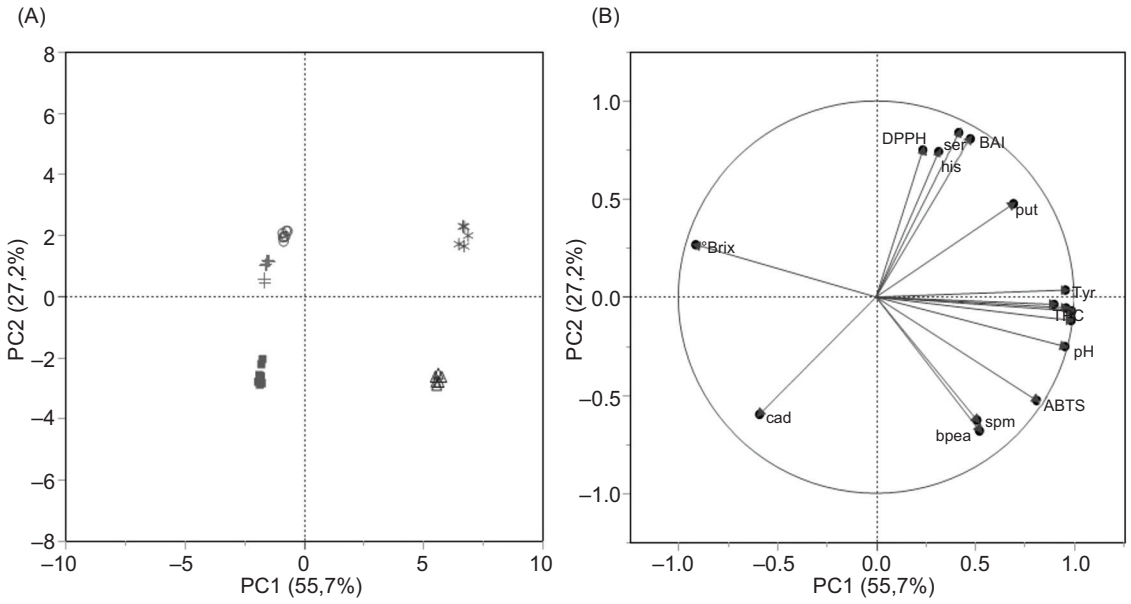

Figure 3. (A) Principal components analysis (PCA) scores and (B) loading plots of tomato samples: Sugarland (circles), Bamano (squares), Dulcemiel (crosses), control fresh (stars), control canning (triangles).

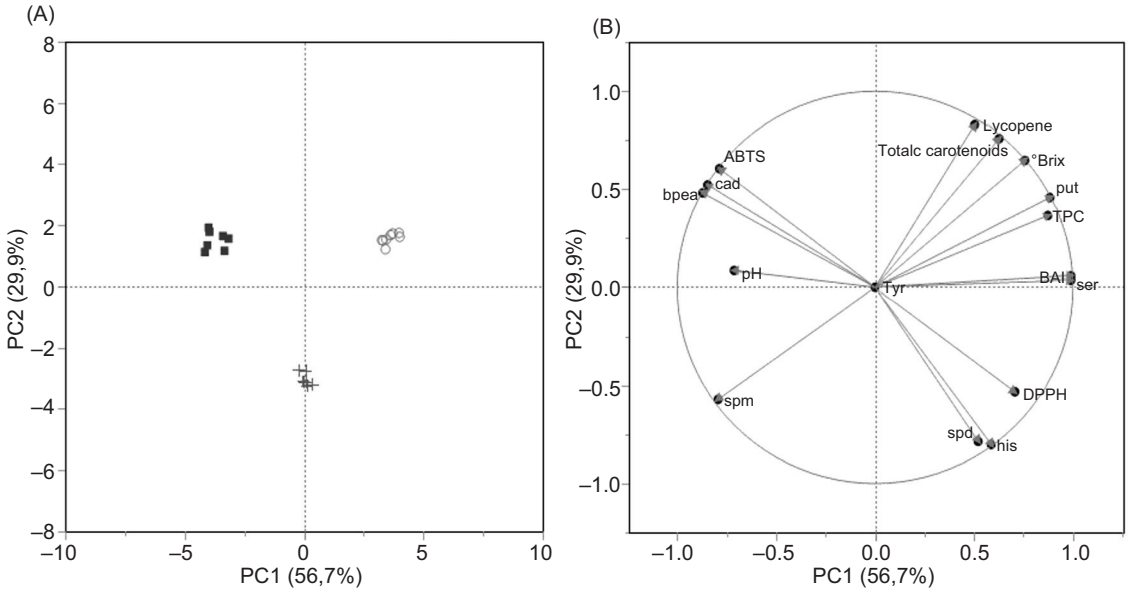

Figure 4. (A) Principal components analysis (PCA) scores and (B) loading plots of tomato samples: Sugarland (circles), Bamano (squares), and Dulcemiel (crosses).

results of the PC explorative analysis were in accordance with the experimental ones (Guerreiro *et al.*, 2013).

The good results of PCA analysis were also confirmed by CA, reported in Figure 5. This analysis pointed out general similarities or differences in the profile of bioactive compounds of the investigated cultivars. The first level of dendrogram demonstrates two clusters: the first one comprises control cultivars, and the second one by three new cultivars (Bamano, Dulcemiel, and Sugarland). At the lower level of dendrogram, the first cluster is divided in two parts by separating control cultivars as the samples used for fresh market and that for canning industry. The second cluster (three new cultivars) was also divided into two parts: the first part consisting of Bamano samples, and the other one comprising Dulcemiel and Sugarland samples. Therefore, these two cultivars exhibited similar contents to the compounds examined herein. CA and PCA results demonstrated differentiation among new cultivars and the control.

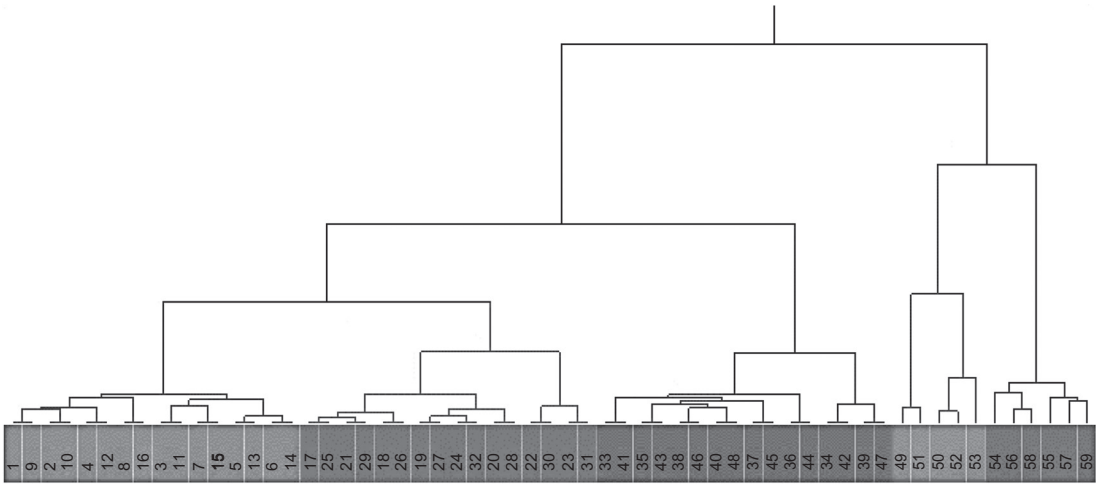

Figure 5. Cluster analysis: Sugarland (samples 1–16), Dulcemiel (samples 17–32), Bamano (samples 33–48), control fresh (samples 49–53), and control canning (samples 54–59).

Conclusion

This study assessed the quality and safety of three new cherry tomato cultivars through bioactive compounds evaluation. All the samples came from the same Italian region to minimize differences because of production factors (e.g., climate, soil, etc.). BAs and antioxidant fractions were investigated in Bamano, Dulcemiel, and Sugarland varieties, besides evaluation of physicochemical characteristics. The results were also compared with two control cultivars usually involved in the fresh market and canning industry. The new cultivars had meager amount of HIS (<LOQ 0.57 ± 0.02 mg/kg) and TYR (<LOQ) as well as an interesting amount of SER (132.47 ± 2.05 mg/kg–266.87 ± 11.16 mg/kg). Therefore, quality features were assessed in addition to the absence of spoilage indicators. The antioxidant evaluation was conducted by TPC, anti-radical assays, and total carotenoids and lycopene contents. Comparison with control cultivars demonstrated different physicochemical properties, lower content in total BAs, and lower antioxidant compounds. Finally, a chemometric evaluation of bioactive compounds was conducted by PCA and CA. Different profiles of analyzed compounds enabled a successful differentiation of new cultivars and the control. Therefore, the chosen bioactive compounds resulted in suitable markers for quality and safety assessment of analyzed samples. However, this research could be a good start for new possible investigations. Each variety needs additional experimentation for full characterization of antioxidant fraction and a shelf-life study to evaluate the post-harvest decay. An interesting aspect could be the application and assessment of these tomatoes in processed products.

Conflict of interest

The authors declare that they have no conflict of interest in the subject matter or materials discussed in this manuscript.

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