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# Characterization of traditional tomato varieties grown in organic conditions

F. Gonzalez-Cebrino[1], M. Lozano[1], M. C. Ayuso[2]*, M. J. Bernalte[2], M. C. Vidal-Aragon[3] and D. Gonzalez-Gomez

[1] *Instituto Tecnológico Agroalimentario de Extremadura. Junta de Extremadura. Ctra. San Vicente, s/n. 06071 Badajoz. Spain*
[2] *Escuela de Ingenierías Agrarias. Universidad de Extremadura. Ctra. Cáceres, s/n. 06007 Badajoz. Spain*
[3] *Centro Universitario Santa Ana. Apdo. de Correos 90. 06200 Almendralejo (Badajoz). Spain*

## Abstract

Organic horticulture is a sustainable agricultural model that can provide high quality products and allows conservation of genetic diversity. Traditional tomato varieties are well adapted to organic production and they have the organoleptic characteristics demanded by consumers. Seven traditional tomato varieties were studied: BGV-001020, BGV-000998, BGV-001000, BGV-004123, CIDA-44-A, CIDA-62, CIDA-59-A, and they were compared with a tomato Marmande-type commercial cv. 'Baghera', all them grown under organic production. Several quality variables were measured to establish whether any of the traditional varieties might be suitable for commercial production. CIDA-62 was shown to be the most promising variety. It produces tomatoes of very high quality under organic conditions. It excels in terms of bioactive compounds such as vitamin C (459.22 mg kg$^{-1}$ fw) and lycopene (62.25 mg kg$^{-1}$ fw) and in its total antioxidant activity (43.58 mg Trolox/100 g fw). It is also outstanding in terms of its sugar content (4.56% fructose and glucose combined) and of its total soluble solids content (6.22°Brix). All of these variables are associated with both sensory quality and health benefits. Other varieties that emerged with relatively high levels of total soluble solids content, lycopene, vitamin C and total antioxidant activity were BGV-004123 and BGV-001020.

**Additional key words**: bioactive compounds; landrace; organic horticulture production; quality; *Solanum lycopersicum*.

## Resumen

### Caracterización de variedades tradicionales de tomate producidas en cultivo ecológico

La horticultura ecológica es un modelo de agricultura sostenible que puede proporcionar productos de alta calidad y permite la conservación de la diversidad genética. Las variedades tradicionales de tomate están bien adaptadas a la producción ecológica, y presentan las características organolépticas demandadas por los consumidores. Siete variedades tradicionales de tomate han sido estudiadas: BGV-001020, BGV-000998, BGV-001000, BGV-004123, CIDA-44-A, CIDA-62, CIDA-59-A, y se han comparado con una variedad comercial tipo Marmande ('Baghera'), todas ellas producidas en condiciones de cultivo ecológico. Se han evaluado diversas variables de calidad con el fin de establecer si alguna de las variedades tradicionales podría ser seleccionada para su producción ecológica comercial. La variedad CIDA-62 se ha mostrado como la más interesante. Sobresale en compuestos bioactivos como son vitamina C (459,22 mg kg$^{-1}$ pf) y licopeno (62,25 mg kg$^{-1}$ pf), y su actividad antioxidante total (43,58 mg Trolox/100 g pf). También destaca por el contenido en azúcares (4,56% la suma de fructosa y glucosa) y sólidos solubles totales (6,22°Brix). Todas estas variables están relacionadas con la calidad organoléptica y los beneficios para la salud. Otras variedades que presentan buenas características, con alto contenido en sólidos solubles totales, licopeno, vitamina C y actividad antioxidante total son BGV-004123 y BGV-001020.

**Palabras clave adicionales**: calidad; compuestos bioactivos; horticultura ecológica; *Solanum lycopersicum;* variedades tradicionales.

* Corresponding author: cayuso@unex.es
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Abbreviations used: COMAV (Instituto Universitario de Conservación y Mejora de la Agrodiversidad Valenciana), fw (fresh weight), HAA (hydrophilic antioxidant activity), IMIDA (Instituto Murciano de Investigación y Desarrollo Agrario), INTAEX (Instituto Tecnológico Agroalimentario de Extremadura), RID (refractive index detection), TAA (total antioxidant activity), TSS (total soluble solids).

## Introduction

Traditional agricultural crops have been progressively displaced in recent years as a result of developments in both cultivation methods and plant varieties. Old or autochthonous strains of many cultivated species have been replaced by genetically or biotechnologically improved varieties (Díaz del Cañizo *et al*., 1998; Cebolla-Cornejo *et al*., 2002) that are more productive and more resistant to diseases and pests. Germplasm collections are effective tools to preserve the genetic variability in crop species by avoiding, as much as possible, genetic erosion. Germplasm banks provide an identification and description for each accession, but it is insufficient information when the material is going to be reintroduced or used in a breeding program.

There is currently concern to encourage sustainable and balanced models of agricultural production, consistent with better conservation both of genetic diversity and of the wider environment. On the other hand, consumers also miss the traditional flavor of tomato and demand healthy products rich in bioactive compounds. Therefore, the use of new cultivars, employed in intensive production, is not recommended for organic production. A good alternative might be the utilisation of traditional varieties, better adapted to particular agroclimatic conditions (Díaz del Cañizo *et al*., 1998).

It is relevant to consider the importance that organic cultivation is acquiring in the context of world food production as a whole. There is consistent growth in consumer demand for organic produce, different in character from conventional foods but nevertheless of excellent quality (Rivera and Brugarolas, 2003). This demand is recognised by the fruit and vegetable sectors, which shows a growing interest in promoting the survival of traditional varieties in order to secure the best methods of producing and marketing quality produce. Organic horticulture represents a sustainable and alternative agricultural model with the potential to provide both environmental improvements and high-quality outputs (González *et al*., 2002).

The tomato (*Solanum lycopersicum* L.) stands out among horticultural crops as one of the most versatile and important on a global scale. It is one of the most widely cultivated vegetables both for fresh and processed produce, and its consumption is of great nutritional importance (Rao *et al*., 1998; Lozano *et al*., 2001; García-Closas *et al*., 2004; Hernández Suárez *et al*., 2008).

A number of epidemiological studies suggest that the consumption of tomatoes and of products derived from them reduces the risk of contracting chronic disorders such as cardiovascular diseases and cancer (Giovannucci, 1999; Willcox *et al*., 2003). It has been shown that a regular intake of small quantities of tomato and derivated products increases cellular protection against DNA damage induced by oxidising compounds. This protection is ascribed to antioxidants such as lycopene, vitamin C and other functional compounds (Toor and Savege, 2005; Raffo *et al*., 2006).

Lycopene is the carotenoid responsible for the red colour of tomatoes (Lozano *et al*., 2001; Martínez-Valverde *et al*., 2002; Javanmardi and Kubota, 2006) and the principal one in ripe tomatoes, where it accounts for 80% of total pigments (Lin and Chen, 2005). Vitamin C also plays an important role in human health, which includes beneficial effects on the immune system and on diseases such as Alzheimer's (Odriozola-Serrano *et al*., 2008). Tomatoes are an important source of these antioxidants (Raffo *et al*., 2006). In Spain, they represent the primary source of lycopene (71.6%) and the second of vitamin C (12.0%) as a result of relatively high levels of consumption (García-Closas *et al*., 2004).

The coordinated efforts of a multidisciplinary group have allowed choosing those traditional tomato varieties that better suit to organic production in the Spanish Southwest. Growing them in actual field conditions allowed us to know which of them were more productive and better adapted to organic production, with better visual and sensory quality (Gragera-Facundo *et al.,* 2008). Among 14 accessions, seven were selected. The objective of the present study was the physicochemical and functional characterisation of these seven traditional varieties of tomato. Their properties were compared with those of a commercial cultivar in order to identify traditional varieties that may be of interest for organic production, with high levels of lycopene and of other antioxidants beneficial to human health.

## Material and methods

### Plant material

During the 2007 season, a total of 14 traditional varieties of tomato obtained from the Institute of Agricultural and Food Research and Development (IMIDA) (Murcia, Spain) and the Centre for the Conservation and Improvement of Agrodiversity (COMAV) (Valencia, Spain), and one Marmande-type commercial cultivar, 'Baghera', from Clause (Portes lès Valence, France), were cultivated under organic conditions (Gragera-Facundo *et al.,* 2008). The trial was carried out at the Agricultural Research Centre La Orden-Valdesequera (Badajoz, Spain). Seven of the traditional varieties were selected for analysis, together with the commercial cv. 'Baghera', on the basis of productivity criteria (high agronomic yields), sensory evaluation and suitability for commercialization (Gragera-Facundo *et al.,* 2008). Varieties that produced fruits with morphological or phytopathological defects and/or with mechanical damage were rejected.

Tomatoes were harvested at red ripening stage (USDA, 1991) and were taken to the Institute of Agricultural and Food Technology (INTAEX) (Badajoz, Spain). The varieties identified for testing were BGV-001020, BGV-000998, BGV-001000, BGV-004123, CIDA-44-A, CIDA-62, CIDA-59-A and 'Baghera' (Table 1). Fruits of each variety were divided into two groups: one to be analysed fresh and the other to be kept frozen at –20°C prior to analysis. The fresh samples were used to determine total soluble solids (TSS), pH, titratable acidity, firmness, colour and sugar content. The frozen fruits were used to measure lycopene and vitamin C contents and total antioxidant activity (TAA).

## Analysis

### *Total soluble solids content (TSS), pH, titratable acidity and sugar content*

TSS, pH, titratable acidity and sugar content were determined for each variety using a homogenate prepared from five fruits in a commercial mixer (Thermomix, Vorwerk España M.S.L., Madrid, Spain). TSS was measured by means of an RE40 digital refractometer (Mettler Toledo, S.A.E., Coslada, Madrid, Spain). Two measurements were performed for each homogenate and the results were expressed as °Brix. Both pH and titratable acidity were determined using a DL50 Graphix automatic titrator (Mettler Toledo, S.A.E., Coslada, Madrid, Spain) against an alkaline solution of 0.1 N NaOH to pH 8.1. Two measurements were performed for each homogenate and the results were expressed as percentage citric acid. The maturity index has been calculated as the ratio TSS to titratable acidity, and the flavour index [(TSS/20 × titratable acidity) + titratable acidity] has also been calculated.

The concentrations of sugars (glucose and fructose) were measured using 1 g of each homogenate made up to 10 mL with Milli-Q water. The samples were passed through a 0.45 µm Millipore filter and injected into an 1100 HPLC chromatograph (Agilent Technologies, Inc., Palo Alto, CA, USA) with a GL Sciences Inertsil NH-2 4.6 × 250 mm – 5 µm column maintained at 40°C. Acetonitrile/Milli-Q water (70:30) was used as the mobile phase and detection was by refractive index (RID) (Lozano *et al.,* 2009). The external standard technique was used for quantification and the results were expressed as g/100 g fw of glucose and fructose.

### *Firmness*

The firmness of the fruit was evaluated by means of compression tests using a TA.XT2i texture analyser (Aname, Pozuelo, Madrid, Spain) with a cylindrical flat-plate probe, 100 mm in diameter, a displacement velocity of 2 mm $s^{-1}$ and a deformation of 2%. Five fruits were used from each sample and two measurements were taken from diametrically opposite regions

**Table 1.** Sources and origins of the studied varieties

| Variety | Source[1] | Origin | Local name | Fruit type |
|---|---|---|---|---|
| BGV-001020 | COMAV | Almería | Tomate Marmande | Flattened and ribbed |
| BGV-000998 | COMAV | Jaén | Tomate de Siles | Flattened and ribbed |
| BGV-001000 | COMAV | Granada | Tomate del país | Flattened and ribbed |
| BGV-004123 | COMAV | Cáceres | Tomate gordo rosa | Rounded |
| CIDA-44-A | IMIDA | Murcia | Tomate de pera | Rounded |
| CIDA-62 | IMIDA | Murcia | Tomate de pera | Cherry |
| CIDA-59-A | IMIDA | Murcia | Tomate murciano | Rounded |
| Baghera | Clause | Commercial | Tomate Marmande | Rounded |

[1] COMAV: Centre for the Conservation and Improvement of Agrodiversity in Valencia. IMIDA: Institute of Agricultural and Food Research and Development in Murcia.

of each fruit. The resulting force-displacement curves were used to determine maximum force (N) and the slope of the force-deformation curve (N $mm^{-1}$).

### *Skin colour*

Skin colour was assessed by colourimetry, using a CM-3500d spectrophotometer (Konica Minolta/Aquateknica, S.A., Valencia, Spain) and the illuminant D65. Measurements were made by reflectance with a circular measurement area of 30 mm diameter. Five fruits were used from each sample, with two measurements taken from diametrically opposite regions of each fruit. The following CIELab variables were obtained: L* (lightness), a* (red intensity), b* (yellow intensity).

### *Lycopene and vitamin C*

Concentrations of lycopene were determined by HPLC after extraction with a solution of acetone: ethanol:hexane (1:1:2) and elimination of the solvent. The residue was diluted in HPLC acetone, passed through a 0.45 µm Millipore filter and injected into an 1100 HPLC chromatograph (Agilent Technologies, Inc., Palo Alto, CA, USA) with an Agilent LiChrosorb RP-18 4.6 × 200 mm – 10 µm column maintained at 30°C. Acetone/Milli-Q water was used as the mobile phase, at 75:25 to minute 5, changing gradually to 95:5 at minute 10, maintained at this ratio for seven further minutes and then returned to the initial proportions. The flow rate was 1 mL $min^{-1}$, detection was by DAD at 460 nm, quantification was carried out by the external standard method. Extractions were carried out in quadruplicate and the results were expressed as mg of lycopene per kilogram of fresh weight (mg $kg^{-1}$ fw) (Sabio *et al*., 2003).

Vitamin C content was measured by HPLC. EDTA/ $H_3PO_4$ (85%) was used as an extraction solution and the extracted samples were filtered (Millipore 0.45 µm) and injected into a 1050 HPLC chromatograph (Agilent Technologies, Inc., Palo Alto, CA, USA) with an Agilent Zorbax SB-C8 4.6 × 250 mm – 5 µm column maintained at 30°C. A buffer solution of 50 mM acetic acid/ acetate (pH 4) was used as the mobile phase. The flow rate was 0.5 mL $min^{-1}$, detection was at 260 nm, quantification was performed using the external standard technique. Analyses were carried out in quadruplicate and the results were expressed as mg of vitamin C $kg^{-1}$ fw (Bernalte *et al.,* 2007).

### *Total antioxidant activity (TAA)*

TAA was estimated from the activity of hydrosoluble compounds (hydrophilic antioxidant activity, HAA), according to the method established by Cano *et al*. (1998), slightly modified. Briefly, 20 µL of freshly prepared tomato juice from the homogenate was placed in a spectrometric cuvette, and 1 mL of the radical cation ABTS [2,2'-azinobis(3-ethylbenzoithiazolone 6-sulphonate)] was added. The measurement was carried out in a UV-2401 PC Shimadzu spectrophotometer (Shimadzu Scientific Instruments, Inc., Columbia, MD, USA). The initial absorbance value at 730 nm was then compared with the absorbance obtained after 20 min of reaction. The results were expressed as mg of Trolox/100 g of fw. Although only hydrophilic antioxidant activity (HAA) was analysed here, we refer to it as TAA because previous studies have shown that HAA in tomatoes makes up more than 92% of total antioxidant activity (Toor and Savage, 2005).

### *Statistical analysis*

The results were subjected to one-way analysis of variance (ANOVA), means were compared with Tukey's HSD test ($p < 0.05$) and the relationships between variables were tested using Pearson's correlation ($p < 0.01$). SPSS 15.0 (SPSS Inc., Chicago, IL, USA) was used for all analyses.

# Results

## Total soluble solids content (TSS), pH, titratable acidity and sugar content

The results obtained for each of these variables from all the tomato varieties analysed are shown in Table 2. The highest values for TSS and titratable acidity were found for CIDA-62 (6.22°Brix, 0.35% citric acid) and BGV-004123 (5.88°Brix, 0.33% citric acid) without differences among them.

The maturity index (ratio TSS to titratable acidity) gives a good indication of tomatoes ripeness. BGV-001020 (high maturity index, 18.68) and BGV-000998 (low maturity index, 13.93) stood out in this study as significantly different ($p < 0.05$) from one another (Table 2). The flavour index [(TSS/20 × titratable aci-

**Table 2.** Quality variables of the studied varieties

| Variety | TSS (°Brix) | pH | Titratable acidity (% citric acid) | Maturity index | Flavour index |
|---|---|---|---|---|---|
| BGV-001020 | 4.48 ± 0.38[a] | 4.30 ± 0.06[cd] | 0.24 ± 0.02[ab] | 18.68 ± 2.87[b] | 1.18 ± 0.13[abc] |
| BGV-000998 | 4.07 ± 0.20[a] | 4.17 ± 0.08[ab] | 0.30 ± 0.06[abc] | 13.93 ± 2.68[a] | 1.00 ± 0.77[a] |
| BGV-001000 | 4.05 ± 0.29[a] | 4.26 ± 0.05[bcd] | 0.24 ± 0.04[a] | 17.49 ± 3.61[ab] | 1.11 ± 0.14[abc] |
| BGV-004123 | 5.88 ± 0.15[b] | 4.21 ± 0.03[abc] | 0.33 ± 0.02[c] | 17.69 ± 1.24[ab] | 1.22 ± 0.04[bc] |
| CIDA-44-A | 4.50 ± 0.00[a] | 4.15 ± 0.01[a] | 0.31 ± 0.00[c] | 14.36 ± 0.00[ab] | 1.03 ± 0.00[a] |
| CIDA-62 | 6.22 ± 0.31[b] | 4.34 ± 0.04[d] | 0.35 ± 0.04[c] | 18.05 ± 1.32[ab] | 1.25 ± 0.03[c] |
| CIDA-59-A | 4.52 ± 0.24[a] | 4.22 ± 0.02[abc] | 0.31 ± 0.01[bc] | 14.69 ± 1.35[ab] | 1.04 ± 0.06[ab] |
| Baghera | 4.33 ± 0.37[a] | 4.18 ± 0.04[ab] | 0.31 ± 0.02[abc] | 14.26 ± 1.90[ab] | 1.02 ± 0.08[a] |

Data are expressed as mean values ± SD (n = 4). By column, data with different letters differ statistically ($p < 0.05$).

dity) + titratable acidity] has also been calculated; two varieties CIDA-62 and BGV-004123, stand out in this variable, with a value of 1.25 and 1.22 respectively. The results for these two indexes suggest that BGV-001020, CIDA-62 and BGV-004123 would be the best varieties in this context.

The fructose and glucose contents were similar in all of the varieties studied here, ranging from 1.29 g/100 g fw (CIDA-59-A) to 2.27 g/100 g fw (CIDA-62) for fructose and from 1.35 g/100 g fw (CIDA-59-A) to 2.29 g/100 g fw (CIDA-62) for glucose (Fig. 1), and the ratios of glucose to fructose were between 0.9 and 1. Significantly higher ($p < 0.05$) levels were found in CIDA-62 and BGV-004123, which were also the varieties with the greatest total sugar concentrations. A highly significant correlation ($p < 0.01$) was found between the two sugars, with a coefficient $r$ of 0.936.

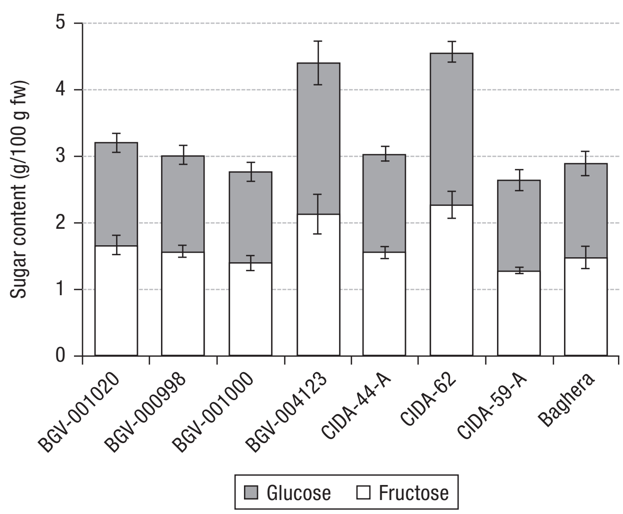


**Figure 1.** Sugar contents of the studied varieties. Data are expressed in mean values ± SD (n = 4).

## Firmness

The firmness of fruit is defined by the maximum force (N) and the slope (N mm$^{-1}$) of the force-displacement curve obtained from compression tests. The values obtained in this study varied widely, with significant differences ($p < 0.05$) between varieties (Table 3). The results for maximum force were especially variable, with CIDA-62 returning the lowest value (1.08 N) and BGV-001000 the highest (6.47 N).

## Skin colour

Our results (Table 3) confirm that CIDA-62 produces the most intensely red fruit, significantly different ($p < 0.05$) from the rest of the varieties.

## Lycopene and vitamin C

The varieties with the greatest concentrations of lycopene were CIDA-62 (62.25 mg kg$^{-1}$ fw) and BGV-004123 (55.02 mg kg$^{-1}$ fw), followed by 'Baghera' (46.44 mg kg$^{-1}$ fw) (Table 4). In this study, a highly significant negative correlation ($p < 0.01$) was also found between h* and lycopene content ($r = -0.488$).

The values for vitamin C ranged from 459.22 mg kg$^{-1}$ fw in CIDA-62 to 160.31 mg kg$^{-1}$ fw in BGV-000998 (Table 4). Both CIDA-62 and BGV-004123 (384.70 mg kg$^{-1}$ fw) contained levels significantly higher ($p < 0.05$) than those of the remaining varieties (160.31 to 273.52 mg kg$^{-1}$ fw).

## Total antioxidant activity (TAA)

TAA varied between 22.65 mg Trolox/100 g fw ('Baghera') and 43.58 mg Trolox/100 g fw (CIDA-62),

**Table 3.** CIELab parameters and colour index of the skins, and textural variables of the studied varieties

| Variety | Colour parameters | | | | Firmness | |
|---|---|---|---|---|---|---|
| | L* | a* | b* | a*/b* | Force (N) | Slope (N mm$^{-1}$) |
| BGV-001020 | 44.60 ± 5.02$^{de}$ | 25.27 ± 3.61$^{b}$ | 35.46 ± 6.41$^{bc}$ | 0.72 ± 0.20$^{ab}$ | 5.64 ± 1.41$^{cd}$ | 3.31 ± 0.64$^{cd}$ |
| BGV-000998 | 37.45 ± 5.38$^{ab}$ | 19.70 ± 3.59$^{a}$ | 31.84 ± 7.86$^{b}$ | 0.66 ± 0.18$^{a}$ | 4.75 ± 1.51$^{c}$ | 2.84 ± 0.78$^{bc}$ |
| BGV-001000 | 47.25 ± 5.19$^{e}$ | 24.39 ± 5.79$^{b}$ | 37.82 ± 6.49$^{c}$ | 0.64 ± 0.23$^{a}$ | 6.47 ± 1.99$^{d}$ | 3.86 ± 1.13$^{d}$ |
| BGV-004123 | 39.27 ± 4.43$^{bc}$ | 23.23 ± 5.94$^{ab}$ | 30.94 ± 4.57$^{b}$ | 0.77 ± 0.24$^{abc}$ | 2.56 ± 0.85$^{b}$ | 2.10 ± 0.68$^{ab}$ |
| CIDA-44-A | 42.78 ± 4.46$^{cd}$ | 21.84 ± 3.54$^{ab}$ | 33.19 ± 4.50$^{bc}$ | 0.68 ± 0.18$^{a}$ | 5.30 ± 0.86$^{cd}$ | 3.98 ± 0.71$^{d}$ |
| CIDA-62 | 33.68 ± 1.82$^{a}$ | 21.54 ± 2.39$^{ab}$ | 16.36 ± 2.24$^{a}$ | 1.34 ± 0.25$^{d}$ | 1.08 ± 0.34$^{a}$ | 1.26 ± 0.38$^{a}$ |
| CIDA-59-A | 39.18 ± 3.91$^{bc}$ | 30.67 ± 3.89$^{c}$ | 33.69 ± 5.09$^{bc}$ | 0.93 ± 0.17$^{c}$ | 3.05 ± 0.64$^{b}$ | 2.44 ± 0.46$^{bc}$ |
| Baghera | 40.00 ± 3.96$^{bc}$ | 31.01 ± 5.63$^{c}$ | 35.22 ± 4.74$^{bc}$ | 0.90 ± 0.20$^{bc}$ | 4.83 ± 2.27$^{c}$ | 4.01 ± 2.05$^{d}$ |

Data are expressed as mean values ± SD (n = 10). By column, data with different letters differ statistically ($p < 0.05$).

with the latter returning a significantly higher value than any of the others (Table 4).

Highly significant correlations ($p < 0.01$) were found between TAA, levels of lycopene and levels of vitamin C. The relationship between lycopene and vitamin C contents was especially marked, with a coefficient $r$ of 0.852. Also of interest are correlations between TAA and vitamin C content ($r = 0.679$) and between lycopene levels and TAA ($r = 0.643$), each highly significant ($p < 0.01$).

## Discussion

The flavour of tomatoes is strongly affected by TSS, pH and titratable acidity, which are therefore considered good indicators of sensory quality (Thybo *et al*., 2006). The results obtained for TSS, pH and titratable acidity from all the varieties analysed fell within the range stipulated by Arana *et al*. (2006) for tomatoes of good organoleptic quality.

Flavor is an important quality characteristic in fruit and vegetables (Kader, 2008). According to Hernández Suárez *et al.* (2008), 0.7 is the minimum value of the flavour index [(TSS/20 × titratable acidity) + titratable acidity] for tomato to be considered of acceptable flavour. Our data (Table 2) show that all the varieties analysed here exceed this value. BGV-001020, CIDA-62 and BGV-004123 seem to be the varieties with fruits of greater organoleptic quality than the others as a result of a better balance between TSS and acidity.

Sugars contents obtained by other authors lie between 1.2% for fructose and 1.4% for glucose, slightly lower than those found in this study (Loiudice *et al*., 1995; Osvald *et al*., 2001; Hernández Suárez *et al*., 2008). The mean sugar concentration in tomatoes given in food composition tables varies between 3 and 3.5% (Moreiras *et al*., 2005). However, this variable is known to be highly influenced by variety, method of cultivation, and dates and places of production, such that it is possible to find values outside this range (Hernández

**Table 4.** Bioactive compound contents and TAA of the studied varieties

| Variety | Vitamin C (mg kg$^{-1}$ fw) | Lycopene (mg kg$^{-1}$ fw) | TAA (mg Trolox/100 g fw) |
|---|---|---|---|
| BGV-001020 | 245.90 ± 25.77$^{a}$ | 36.57 ± 7.83$^{abc}$ | 34.56 ± 6.79$^{b}$ |
| BGV-000998 | 160.31 ± 0.00$^{a}$ | 25.44 ± 1.46$^{a}$ | 25.05 ± 2.29$^{a}$ |
| BGV-001000 | 273.52 ± 3.42$^{a}$ | 37.79 ± 10.31$^{abc}$ | 28.33 ± 3.56$^{ab}$ |
| BGV-004123 | 384.70 ± 72.51$^{b}$ | 55.02 ± 3.16$^{bc}$ | 35.93 ± 4.43$^{b}$ |
| CIDA-44-A | 226.53 ± 35.72$^{a}$ | 29.47 ± 1.15$^{ab}$ | 26.81 ± 1.01$^{a}$ |
| CIDA-62 | 459.22 ± 27.92$^{b}$ | 62.25 ± 11.33$^{c}$ | 43.58 ± 4.81$^{c}$ |
| CIDA-59-A | NA | 27.00 ± 15.03$^{a}$ | 23.01 ± 3.73$^{a}$ |
| Baghera | 233.61 ± 23.20$^{a}$ | 46.44 ± 19.00$^{abc}$ | 22.65 ± 2.94$^{a}$ |

Data are expressed as mean values ± SD (n = 4). By column, data with different letters differ statistically ($p < 0.05$). NA: CIDA-59-A was not analysed for vitamin C content.

Suárez *et al*., 2008). The ratios of glucose to fructose, between 0.9 and 1, were values consistent with those obtained by Hernández Suárez *et al*. (2008). In the present study, total sugar contents varied from 2.64% to 4.56% in CIDA-59-A and CIDA-62 respectively. Our figures are generally high, which may be a result of the tomatoes being grown in organic conditions and of their ripening on the plant.

Firmness values of these tomato varieties are low due to the ripening stage. According to Zapata *et al.* (2007), firmness is a very important component of quality, both in terms of commercialization and of the assessment of organoleptic properties.

The colour of tomatoes is one of the most important aspects of their quality, with a strong influence on consumer choice and acceptability (Lozano *et al*., 2001; Zapata *et al*., 2007). The ratio a*/b* is a good indicator of colour in tomatoes, expressing well the changes in colour that occur. Toor *et al*. (2006) obtained values for a*/b* in ripe tomatoes of 1.19, while Zapata *et al*. (2007) specified a minimum value of 0.92 for fruit in a stage of commercial ripeness.

A correlation has been established between lycopene content and the colour index a*/b* ($r = 0.506$), such that those tomato varieties with higher colour indices were also those with greater lycopene levels (López Camelo and Gómez, 2004).

There is an extensive literature on the lycopene content of fresh tomatoes, revealing a wide variety of concentrations. Abushita *et al*. (2000), Gómez *et al*. (2001) and Lenucci *et al*. (2006) found levels of 5 to 13 mg/100 g fw in tomatoes grown in open air. Other studies found lower concentrations (Thompson *et al*., 2000; Martínez-Valverde *et al*., 2002; Toor *et al*., 2006), ranging from 1.1 to 6.5 mg/100 g fw. Spagna *et al.* (2005) obtained values of 15.91 to 17.73 mg/100 g fw from traditional varieties, slightly greater than those they found in commercial cultivars (11.12 to 14.83 mg/100 g fw), and Lenucci *et al*. (2006) found levels in varieties rich in lycopene between 17.5 and 25.3 mg/100 g fw. This variability stems from the fact that lycopene concentrations in fresh tomatoes depend on a range of factors, including especially the variety, the method of cultivation, irrigation, environmental conditions, the date of harvesting, the ripening stage and post-harvest handling (Abushita *et al*., 2000; Thompson *et al*., 2000; Gómez *et al*., 2001; Raffo *et al*., 2002; Toor and Savage, 2005, 2006; Toor *et al*., 2006; Javanmardi and Kubota, 2006; Odriozola-Serrano *et al*., 2008; Hernández Suárez *et al*., 2008; Favati *et al*., 2009). Correlations between lycopene content, h* and a*/b* are consistent with results of other authors (Thompson *et al*., 2000; López Camelo and Gómez, 2004; Odriozola-Serrano *et al*., 2008).

The values for vitamin C in CIDA-62 and BGV-004123 are significantly higher ($p < 0.05$) than those of the other varieties, and greater than those found by other authors. The results from the other varieties were similar to those cited in the literature, which vary widely between 7 and 30 mg/100 g fw. This variability, like that in lycopene content, results from a number of factors such as variety and the conditions during production and after harvesting (Abushita *et al*., 2000; Raffo *et al*., 2002; George *et al*., 2004; Spagna *et al*., 2005; Adalid *et al*., 2007; Zapata *et al*., 2007; Odriozola-Serrano *et al*., 2008; Favati *et al.*, 2009).

The TAA results, obtained in this study, are within the range of those obtained by other authors, who found levels of between 80 and 200 μmol Trolox/100 g fw (Toor *et al*., 2006; Odriozola-Serrano *et al*., 2008). The antioxidant capacity of tomatoes depends on a large number of phytochemical compounds and the interactions that occur between them (Odriozola-Serrano *et al*., 2008). As with previously described attributes, TAA depends on numerous factors such as variety, growing and environmental conditions.

TAA, lycopene and vitamin C, all they related with functional quality in tomato, are highly significant correlated ($p < 0.01$) in these varieties, consistent with those found in the literature.

The higher the vitamin C and lycopene content in tomatoes the greater antioxidant capacity. These correlations were also observed by other authors in tomato fruits (Adalid *et al*., 2007; Odriozola-Serrano *et al*., 2008).

In general, traditional varieties, when compared with the commercial cultivar 'Baghera', show a higher TTS and sugar content, maturity and flavour indexes; 'Baghera' also exhibits low level of TAA and vitamin C.

As final conclusions, the variety CIDA-62 stands out quantitatively from the others, mainly because of its high vitamin C and lycopene contents and its high TAA. It also has higher levels of sugars, which are partly responsible for flavour. Other varieties that showed good quality characteristics are BGV-004123 and BGV-001020. We conclude, therefore, that these three varieties studied have the greatest potential for commercial use in organic tomato production.

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