Nutritional and bioactive compounds in dried tomato processing waste

Violeta Nour, Tatiana D. Panaite, Mariana Ropota, Raluca Turcu, Ion Trandafir, and Alexandru R. Corbu

Department of Horticulture & Food Science, University of Craiova, Craiova, Romania.

ABSTRACT

This research investigated the nutritional and antioxidant composition of tomato processing waste with the aim to enable the development of new alternatives for the recycling of this by-product. The samples of dried tomato waste were found to contain 176.2 g/kg protein, 21.9 g/kg fat, 524.4 g/kg crude fiber and 42.1 g/kg ash. The essential amino acids represented 34.2% of total protein, the most abundant being leucine, followed by lysine and isoleucine. Unsaturated fatty acids represent 77.04% of the total fatty acids, linoleic being the major one. The results confirmed that dried tomato wastes contain considerable amounts of lycopene (510.6 mg/kg) and β-carotene (95.6 mg/kg) and exhibited good antioxidant properties. Total phenolics showed average contents of 1229.5 mg GAE/kg, of which flavonoids accounted for 415.3 mg QE/kg. Ellagic and chlorogenic acids were the most abundant phenolic acids while among flavonoids only rutin and myricetin were quantified.

INTRODUCTION

Tomato (Lycopersicon esculentum Mill.) is a widely cultivated vegetable crop, with a world production of over 170 million tons in 2014 (FAOSTAT, 2014). Of these, World Processing Tomato Council estimated that around 40 million tons of tomatoes were processed worldwide to produce tomato juice, paste, puree, ketchup, canned tomatoes and many other food products (WPTC, 2015). Both fresh and processed tomato possesses a high nutritional value, due to its content of vitamins, folates, carotenoids and phenolic compounds (Savatović, Četković, Căndanovici-Brunet, & Dîlas, 2010). Lycopene is the most abundant carotenoid in tomato, accounting for 80–90% of the total carotenoids, but other carotenoids such as a-, b-, γ-, δ-carotene, phytoene, phytofluene and lutein are also present (Calvo, García, & Selgas, 2008). Lycopene has attracted the greatest attention in recent years for its potential health benefits (Kong et al., 2010), being the most efficient free radical scavenger, with a capacity found to be more than twice that of β-carotene (Capanoglu, Beekwilder, Boyacioglu, De Vos, & Hall, 2010).

During the industrial processing of tomatoes, large quantities of wastes are generated consisting of peels, seeds, fibrous parts and pulp residues that account for 7.0–7.5% of raw materials (Sogi, Sidhu, Arora, Garg, & Bawa, 2002). The management of tomato wastes represents a worldwide problem for both the environmental and the economical aspects and the recycling or re-usage of these by-products can reduce processing costs (Poli et al., 2011). Although these wastes have no commercial value, they are a rich source of nutrients and highly biologically active compounds. The skins of tomatoes have been found to be richer sources of lycopene and polyphenolic compounds than the pulp (George, Kaur, Khurdiya, & Kapoor, 2004; Toor & Savage, 2005). Tomato seeds have been shown to contain ca. 20% oil of high nutritional quality (Eller, Moser, Kenar, & Taylor, 2010) together with carotenoids, proteins, polyphenols, phytosterols, minerals and fibers (Persia, Parsons, Schang, & Azcona, 2010).
2003; Toor & Savage, 2005; Zuorro, Lavecchia, Medici, & Piga, 2013).

A number of studies have investigated the potential nutritive value of tomato by-products and the effect of their incorporation into the animal feed mixtures. Persia et al. (2003) reported that tomato seeds from tomato canny waste can be supplemented into chick rations at up to 15% without any adverse effects on growth performance while King and Zeidler (2004) showed that tomato pomace could be used as a source of vitamin E in broiler diets to decrease lipid oxidation during heating and long-term frozen storage of meat, and to prolong shelf life.

As tomato wastes are the only by-products that are rich in lycopene, numerous studies have been carried out on the extraction of lycopene from tomato waste (Nobre, Palavra, Pessoa, & Mendes, 2009). Moreover, these wastes could be exploited by the ultrasound-assisted extraction of pectin (Grassino et al., 2016) and for the sustainable production of new polysaccharides with anticytotoxic and antioxidant activity and with the capability to form biofilms (Tommonaro, Poli, De Rosa, & Nicolaus, 2008).

Improving value of tomato waste could be possible through the development of environment-friendly technologies that convert it into new food ingredients or alternative products. Di Donato et al. (2011) investigated the capability of tomato waste to support the microbial biomass production of thermophilic and halophilic microbial strains and to produce enzymes and biopolymers while Moayed, Hashemi, and Safari (2016) showed that tomato waste protein can be valorized to produce antioxidant and antibacterial hydrolysates in a fermentative system. Zuorro, Lavecchia, Medici, and Piga (2014) investigated the feasibility of using tomato waste to produce a tomato oleoresin by pretreating the peel fraction of the waste with cell wall degrading enzymes. The oleoresin was incorporated into tomato seed oil so as to obtain a functional oil with a high lycopene content. Some authors have even investigated the possibility of incorporation of tomato waste powders directly into foods. García, Calvo, and Selgas (2009) reported on the direct addition of dried tomato peel to raw and cooked beef hamburgers while Calvo et al. (2008) developed dry fermented sausages enriched in lycopene by adding dried tomato peel to the meat mixture. In order to enhance protection against lipid oxidation, Alves, Bragagnolo, Da Silva, Skibsted, and Orlien (2012) added tomato waste in pressure-processed minced chicken meat while Benakmoun, Abbeddou, Ammouche, Kefalas, & Gerasopoulos (2008) proposed to enrich low edible oils with carotenoids following direct incorporation of tomato peels. As an alternative approach to elaborate new functional foods, Nour, Ionica, and Trandafir (2015) reported on the effects of the addition of dry tomato waste on the physicochemical, baking and sensorial qualities of the wheat bread while Altan, McCarthy, and Maskan (2008) investigated the extrusion processability of barley flour with the combination of tomato pomace to produce snack foods.

The aim of this work was to determine the content of various nutrients and bioactive compounds (carotenoids, polyphenols, amino and fatty acids) in the waste coming from the tomato processing industries. The results of this study should enable the development of new alternatives for the recycling of this valuable by-product.

**Materials and methods**

**Plant material**

Two shipments of tomato industrial waste (a mixture of skins and seeds) were collected from Leader International S.A., a commercial tomato processing plant in Caracal, Romania. As soon as obtained, by-products were packed in plastic bags and frozen at −25°C. Tomato by-products were subsequently subjected to drying in an industrial automated forced hot air dryer (Blue Spark Systems S.R.L., Romania) at 60°C. The dried material was milled using an electric grinder to pass through a 1-mm mesh. Both shipments of tomato waste were analyzed to determine moisture, crude protein, crude fat and crude fiber content, total phenolics, total flavonoids, lycopene and ß-carotene content and antioxidant activity. The phenolic profile as well as the amino acids and fatty acids profiles were assessed using chromatographic methods. Mineral content was determined using inductively coupled plasma mass spectrometry.

**Proximate composition**

The chemical composition of dried tomato waste was determined according to standard methods: dry matter by the gravimetric method according to ISO 6496 (ISO, 2001), crude protein by the semiautomatic Kjeldahl method according to ISO 5983–2 (2009) using a Kjeltec 2300 analyzer unit (Tecator, Sweden), crude fat by ether extraction (SR ISO 6492, ISO, 2000) using a Soxtec 2055 extraction unit (Tecator, Sweden), crude fiber by digestion with acid and alkali according to ISO 6865 (ISO, 2002) using an automatic analyzer (Fibertec 2010, Tector, Sweden), and ash according to ISO 2171 (ISO, 2010) using a Caloris CL 1206 oven (Romania).

**Determination of lycopene and ß-carotene content**

Lycopene and ß-carotene were determined according to the method of Nagata and Yamashita (1992). Briefly, 1 g tomato waste powder was vigorously shaken for 15 min with 16 mL of acetone/hexane (4:6) in a test tube. After phase separation, the light absorption values (A) of the hexane layer at 453, 505, 663 and 645 nm wavelength were recorded using a Varian Cary 50 UV-Vis spectrophotometer (Varian Co., USA).

The following equations were used for calculating the lycopene and ß-carotene contents in milligrams per 100 mL of solvent:

\[
\text{lycopene} = -0.0458 \times A663 + 0.204 \times A645 + 0.372 \times A505 - 0.0806 \times A453 \\
\text{ß-carotene} = 0.216 \times A663 - 1.220 \times A645 + 0.304 \times A505 - 0.452 \times A453
\]

where A663, A645, A505 and A453 are the absorbance at 663, 645, 505 and 453 nm, respectively. The results were expressed in mg per kg.

**Determination of total phenolic content**

The total phenolic content was estimated by the Folin–Ciocalteu’s phenol reagent method, based on the procedure of Singleton and Rossi (1965), using gallic acid as a standard phenolic compound. For extraction, 0.3 g of dried tomato
Determination of total flavonoid content

The flavonoid content of dried tomato waste was determined spectrophotometrically by using the aluminum nitrate method as described by Mohammadzadeh et al. (2007). Briefly, 0.5 mL of tomato waste methanolic extract was mixed with 0.1 mL of 10% aluminum nitrate (AlCl₃), 0.1 mL of 1 M aqueous potassium acetate and 4.3 mL methanol. After 40 min reaction time at room temperature, the absorbance of the mixture was measured at 415 nm using an Evolution 600 UV-Vis spectrophotometer (Varian Co., USA). The total flavonoid content was determined using a standard curve with quercetin and the results were expressed in milligrams of quercetin equivalents (QE) per kg.

Determination of DPPH radical scavenging activity

To measure antioxidant activity, the DPPH (2,2-diphenyl-1-picrylhydrazyl) radical-scavenging assay was carried out according to the procedure described by Oliveira et al. (2008). 3 mL 0.004% (v/v) DPPH in methanol was mixed with the methanol tomato extract (50 μL) and the reaction mixture was vigorously shaken and kept in the dark. Exactly 30 min later, absorbance at 517 nm was read using an Evolution 600 UV-Vis spectrophotometer (Thermo Scientific, USA). DPPH radical scavenging activity of the sample was calculated as follows:

\[
\text{DPPH scavenging activity} (\%) = \left[1 - \frac{A_5}{A_{\text{DPPH}}} \right] \times 100
\]

where \( A_5 \) represents the absorbance of the sample extract with DPPH and \( A_{\text{DPPH}} \) is the absorbance of the DPPH solution without sample. Trolox (6-hydroxy-2,5,7,8-tetramethylchromane-2-carboxylic) was used as the control standard and 80% methanol was used as the blank. Results were expressed in mmol of Trolox equivalents per kg.

Determination of amino acids

Fatty acids content was assessed by fatty acid methyl ester (FAME)/gas chromatography according to ISO/TS 17,764–2 (2008). Fatty acids from the total lipid extracts were converted to their methyl esters by transesterification in methanol containing 3% concentrated sulfuric acid at 80°C for 4 h. Methyl esters of fatty acids were analyzed in a Perkin Elmer-Clarus 500 chromatograph equipped with flame ionization detector (FID) and fitted with a BPX70 capillary column (60 m × 0.25 mm i.d., 0.25 μm film thickness). Column temperature was programmed at 5°C min⁻¹ from 180°C to 220°C. The carrier gas was hydrogen (35 cm s⁻¹ linear velocity at 180°C) and the splitting ratio was 1:100. The injector and detector temperatures were 250 and 260°C, respectively. FAME identification was done by comparison with retention times of the known standards. The results were expressed as g fatty acid per 100 g total fatty acids.

Determination of mineral composition

Calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), manganese (Mn), copper (Cu), chromium (Cr), zinc (Zn) and boron (B) were determined by the inductively coupled plasma mass spectrometry (ICP-MS) technique, while the flame atomic absorption spectrometry (FAAS) was used for potassium (K) quantification. Mineralization of samples was carried out by performing a wet acid digestion in a microwave digestion system (Milestone Ethos EZ, Shelton, CT, USA) set at 180°C for 20 min. The ICP-MS and FAAS measurements were performed by an Elan 9000 inductively coupled plasma mass spectrometer (Perkin Elmer Sciex, Canada) and by an Avanta PM atomic absorption spectrometer in flame (GBC, Australia), respectively. The minerals content was quantified against standard solutions and the results were expressed in mg per kg.

Determination of phenolic compounds

Individual phenolic compounds were determined by reversed-phase HPLC method according to Nour, Trandafir, and Cosmulescu (2013) on a Finningan Surveyor Plus HPLC system (Thermo Electron Corporation, San Jose, CA) including vacuum degasser, Surveyor Plus PCLMPMP pump, Surveyor Plus ASP thermoaautosampler and a PDA5P diode array detector (DAD). The separation was performed on a reversed-phase Hypersil Gold C18 column (5 μm, 250 × 4.6 mm) operated at 20°C. The mobile phase consisted of 1% aqueous acetic acid solution (eluent A) and methanol (eluent B). The gradient program was as follows: 90% A
(27 min), 90% A to 60% A (28 min), 60% A (5 min), 60% A to 56% A (2 min), 56% A (8 min), 56% A to 90% A (1 min) and 90% A (4 min). The injection volume was 5 μL. Simultaneous monitoring was performed at 254, 278 and 300 nm at a flow rate of 1 mL min⁻¹. The methanolic extracts obtained as described above were filtered through nylon syringe filter (0.45 μm) before injection. Each compound was quantified according to the peak area measurements, which were reported in calibration curves of the corresponding standards. The content of phenolic compounds was expressed in mg per kg.

### Statistical analysis

The measurements were performed in triplicate for each sample and results were expressed as mean value ± standard deviation. Statistical analysis was performed using Statgraphic Centurion XVI software (StatPoint Technologies, Warrenton, VA, USA).

### Results and discussion

#### Proximate composition

Dried tomato wastes, consisting of about 22.2% seeds and 77.8% pulp residues and skins, were characterized in terms of macronutrients (proteins, fat, fiber and ash) and the results are shown in Table 1. The proximate composition revealed that the dried tomato wastes contained 176.2 g/kg protein, which is comparable to the crude protein level (189.2 g/kg) found by Salajegheh, Ghazi, Mahdavi, and Mozafari (2012). This result was higher than those reported for dried tomato peel by González, Cid, and Lobo (2011) or by Elbadrawy and Sello (2016) who found 133 and 105 g/kg respectively. These differences could be assigned to the seeds contribution, considering that, in a previous study, crude protein of the seed byproduct (202.3 g/kg) was found approximately twice that of the peel byproduct (100.8 g/kg) (Knoblich, Anderson, & Latshaw, 2005) while Persia et al. (2003) reported a crude protein content of the seed byproduct of 250 g/kg.

The fat content found in our samples (21.9 g/kg) was much lower than that reported in previous studies. González et al. (2011) and Elbadrawy and Sello (2016) found in dried peel a crude fat content of 60 and 40.4 g/kg, respectively, while Knoblich et al. (2005) reported a crude fat content of 32.2 g/kg for peel byproduct and 63.7 g/kg for seed byproduct.

The average level of crude fiber content of dried tomato waste was 524.4 g/kg which is higher than values found by Mansoori, Modiranei, and Kiaei (2008) and Salajegheh et al. (2012) but comparable to the neutral detergent fiber content reported by Paryad and Rashidi (2009) in dried tomato pomace. Grassino et al. (2016) reported 577 and 663 g/kg crude fiber in two tomato peel batches from canning factory while Herrera, Sánchez-Mata, and Cámara (2010) found 800 g/kg total dietary fiber in tomato waste peels, the major component being the insoluble fiber. The differences in crude fat and crude fiber content could be due to different tomato cultivars, growing conditions and processing methods (i.e. the amount of seeds, pulp and skins in the waste). The high fiber content results in poor digestibility and low metabolizable energy contribution to animal and poultry diets (Knoblich et al., 2005) but makes them a good supplement for fiber-rich processed foods (Grassino et al., 2016).

### Amino acids content

The results regarding the amino acids content of dried tomato waste are listed in Table 2. Glutamic acid, a nonessential amino acid, was the most abundant in dried tomato waste (72.1 g/kg). Elbadrawy and Sello (2016) found also glutamic acid as the predominant amino acid in the tomato peel protein fraction. In the present study eight essential amino acids were determined in dried tomato waste, namely leucine, isoleucine, lysine, methionine, phenylalanine, threonine, arginine and valine, representing together 34.2% of total protein.

Among essential amino acids, the most abundant was leucine (10.7 g/kg), followed by lysine (8.8 g/kg) and isoleucine (6.87 g/kg) while the content of methionine was very low (2.7 g/kg). Persia et al. (2003) reported total amounts of methionine, cystine and lysine of 3.9, 4.0 and 13.4 g/kg in dried tomato seeds. Previous studies revealed that peel byproduct was generally lower in essential amino acids than seed byproducts (Knoblich et al., 2005), as a result the amino acids profile of the dried tomato waste will depend on the peel/seed ratio in the waste.

#### Fatty acids content

Fatty acids were determined in dried tomato waste by using gas chromatography and their concentrations are presented in Table 3. The results showed that linoleic acid represents the major fatty acid (51.91% of the total fatty acids) followed by oleic acid (18.50%) while palmitic acid was the main saturated acid (16.32%). The unsaturated fatty acids represented 77.04% of the total fatty acids while the saturated fatty acids count for 22.72%, revealing the domination of the unsaturated fatty acids over saturated fatty acids in dried tomato waste. Results of this study are in good agreement

### Table 1. Proximate composition of dried tomato waste.

| Component (g/kg) | Dried tomato waste (skins + seeds) |
|------------------|-----------------------------------|
| Dry matter       | 946.5 ± 13.2                      |
| Crude protein    | 176.2 ± 7.4                       |
| Crude fat        | 21.9 ± 2.0                        |
| Crude fiber      | 524.4 ± 18.3                      |
| Ash              | 42.1 ± 3.6                        |

### Table 2. Amino acids content of dried tomato waste (g/kg).

| Amino acids | Dried tomato waste (skins + seeds) |
|-------------|-----------------------------------|
| Aspartic acid| 15.7 ± 0.4                        |
| Glutamic acid| 72.1 ± 3.2                        |
| Serine      | 1.7 ± 0.1                         |
| Glycine     | 6.3 ± 0.2                         |
| Threonine   | 5.5 ± 0.2                         |
| Arginine    | 14.6 ± 0.6                        |
| Alanine     | 7.1 ± 0.3                         |
| Tyrosine    | 6.9 ± 0.4                         |
| Valine      | 5.4 ± 0.3                         |
| Phenylalanine| 6.1 ± 0.4                         |
| Isoleucine  | 6.9 ± 0.2                         |
| Leucine     | 10.7 ± 0.4                        |
| Lysine      | 8.8 ± 0.3                         |
| Cystine     | 2.3 ± 0.1                         |
| Methionine  | 2.7 ± 0.2                         |
| Total amino acids| 172.4 ± 6.7                      |
Table 3. Fatty acids profile of dried tomato waste (g fatty acid per 100 g total fatty acids).

Table 3. Perfil de ácidos grasos presentes en los desechos de tomate deshidratado (g de ácido graso por 100 g de ácidos grasos totales)

Fatty acids | Dried tomato waste (skins + seeds) | Dried tomato waste (skins + seeds)
---|---|---
Myristic | C 14:0 | 0.41 ± 0.02
Pentadecanoic | C 15:0 | 0.09 ± 0.03
Pentadecenoic | C 15:1 | 0.09 ± 0.02
Palmitic | C 16:0 | 16.32 ± 0.65
Palmitoleic | C 16:1 | 0.64 ± 0.03
Heptadecanoic | C 17:0 | 0.19 ± 0.01
Heptadecenoic | C 17:1 | 0.52 ± 0.02
Stearic | C 18:0 | 5.43 ± 0.34
Oleic cis | C 18:1 | 18.50 ± 0.83
Linoleic cis | C 18:2n6 | 51.91 ± 1.91
Linolenic y | C 18:3n3 | nd
Linolenic α | C 18:3n6 | 3.35 ± 0.24
Octadecatetraenoic | C18:4n3 | 0.48 ± 0.03
Eicosadienoic | C20(2n6) | 0.15 ± 0.01
Eicosatrienoic | C20(3n6) | 0.07 ± 0.01
Docosadienoic | C22(2n6) | 0.39 ± 0.02
Docosatrienoic | C22(3n6) | 0.55 ± 0.03
Docosatrienoic | C22(3n3) | 0.13 ± 0.01
Eicosapentaenoic | C20(5n3) | 0.26 ± 0.01
Lignoceric | C 24:0 | 0.29 ± 0.02
Other fatty acids | | 0.22 ± 0.01

Fatty acids profile
- Saturated fatty acids (SFA)
  - Saturated fatty acids (SFA)
  - Monounsaturated fatty acids (MUFA)
  - Polyunsaturated fatty acids (PUFA), of which:
    - n-3
    - n-6
  - n-6/n-3
  - Total

with previous findings on dried tomato peel (Elbadrawy & Sello, 2016).

In human nutrition, the high ratio of n-6:n-3 PUFA is known as a risk factor in cancers and coronary heart disease (Enser, 2001). For tomato waste, this ratio was 12.56:1, that is lower than the 15:1 ratio reported in the typical western diet by Simopoulos (2002) but higher than the 10:1 ratio in the typical American diet (Kris-Etherton, Harris, Appel, & American Heart Association Nutrition Committee, 2002).

Minerals content

The results of the analysis of dried tomato waste for mineral content are shown in Table 4. Among macroelements, potassium presented the highest concentration (30,301.7 mg/kg), in good agreement with the results reported by Knoblich et al. (2005) in peel byproduct.

Calcium level (1318.5 mg/kg) was slightly lower than that found by Elbadrawy and Sello (2016) in tomato peel (1600 mg/kg) or by Knoblich et al. (2005) who reported 1800 mg/kg in peel byproduct and 1400 mg/kg in seed byproduct, but slightly higher than the level found by Persia et al. (2003) in tomato processing waste (1100 mg/kg). The levels obtained for magnesium, sodium, iron, manganese and copper were fairly close to those reported by Knoblich et al. (2005) or by Elbadrawy and Sello (2016) for tomato peel byproduct. The sodium content is quite high, which restricts the inclusion of tomato waste in poultry diets (Knoblich et al., 2005).

Table 4. Minerals content of dried tomato waste (mg/kg).

Table 4. Contenido de minerales presentes en los desechos de tomate deshidratado (mg/kg)

| Mineral       | Dried tomato waste (skins + seeds) |
|---------------|-----------------------------------|
| Calcium       | 1318.5 ± 43.3                     |
| Magnesium     | 2109.7 ± 67.8                     |
| Potassium     | 30,301.7 ± 588.1                   |
| Sodium        | 665.5 ± 33.5                      |
| Iron          | 56.3 ± 6.4                        |
| Manganese     | 13.5 ± 2.2                        |
| Copper        | 11.5 ± 2.6                        |
| Chromium      | 3.5 ± 1.3                         |
| Zinc          | 63.3 ± 5.1                        |
| Boron         | 19.5 ± 3.2                        |

Table 5. Total phenolics, total flavonoids, lycopene, β-carotene and DPPH radical scavenging activity

Table 5. Fenólicos totales, flavonoides totales, licopeno, β-caroteno y propiedades de eliminación de los radicales libres presentes en los desechos de tomate deshidratado

| Component     | Dried tomato waste (skins + seeds) |
|---------------|-----------------------------------|
| Total phenolics (mg GAE/kg) | 1229.5 ± 55.5 |
| Total flavonoids (mg QE/kg)  | 415.3 ± 18.2  |
| Lycopene (mg/kg)             | 510.6 ± 21.1  |
| β-Carotene (mg/kg)           | 95.6 ± 3.3    |
| Antioxidant activity (mmol Trolox/kg) | 6.8 ± 0.2   |
in our study (510.6 mg/kg) was comparable with the results reported by Calvo et al. (2008) or Knoblich et al. (2005).

The results confirmed that tomato waste contain considerable amounts of phenolic compounds and carotenoids and exhibited good antioxidant properties, therefore, they could be used as sources of ingredients to make functional foods.

### Phenolic compounds

Phenolic acids and flavonoids are very effective free radical scavengers and several potential health promoting effects have been ascribed to them. The skin and seeds of tomatoes have been found to be richer sources of polyphenolic compounds than the pulp (Martínez-Valverde, Periago, Provan, & Chesson, 2002; Toor & Savage, 2005). Tomato waste, since it contains a significant amount of skin and seeds, is a potential source of natural antioxidants (Savatović et al., 2010).

The content of individual phenolic compounds (mg/kg) of dried tomato waste is shown in Table 6. The most abundant phenolic acids quantified in dried tomato waste were ellagic (143.4 mg/kg) and chlorogenic (76.3 mg/kg) acids. Other phenolic acids determined in lower concentrations were salicylic, gallic, vanillic, coumaric and syringic. The levels of vanillic (26.9 mg/kg) and gallic (17.1 mg/kg) were lower than those found by Elbadrawy and Sello (2016) in tomato peel (33.1 and 38.5 mg/kg, respectively).

Among flavonoids, only rutin and myricetin were detected and quantified. These flavonoids are well known for their high antioxidant activity and ability to scavenge free radicals. Even though the levels of rutin and myricetin were low (29.2 and 63.7 mg/kg, respectively), they are likely to contribute to the total antioxidant activity of the tomato waste. Data on the content of individual phenolic compounds in tomato waste are scarce. Chlorogenic acid and rutin were the most abundant individual phenolics found by García-Valverde, Navarro-González, García Alonso, and Periago (2013) and Slimestad and Verheul (2009) in all studied tomato varieties.

García-Valverde et al. (2013) reported chlorogenic acid content from 16.8 mg/kg to 99.6 mg/kg fw and rutin content ranging from 2.5 to 43.3 mg/kg fw while Slimestad and Verheul (2009) found a large variability in rutin concentration depending on variety and ripening stage, ranging from 6 to 24 mg/kg fw in green and red tomatoes, respectively.

### Conclusions

Results of this study demonstrated that tomato wastes (skins and seeds) possess a high nutritional value based on their content of essential amino acids, fatty acids and minerals, suggesting that they have a substantial potential value as animal feed. However, their extremely high crude fiber content limits their use in poultry diets because of their poor digestibility and low metabolizable energy contribution.

The high carotenoid content in tomato waste, came mainly from tomato skins, led to a rising interest for the extraction of lycopene and β-carotene since they are widely used as food colorants, functional food ingredients, or as component of dietary supplements, pharmaceuticals and cosmetic products. However, in order to avoid lycopene extraction, that has been shown to be inefficient or expensive, the direct addition of dried tomato waste to food products could be a way to use these wastes to obtain new food products enriched in bioactive compounds. Apart from lycopene, tomato by-products are rich in phenolic compounds, with high antioxidant activity, which will help increase the functionality of the foods to which they are added.

A better knowledge of the composition of these by-products from the tomato processing industry could lead to their conversion in products of higher value and to the improvement of the tomato waste management, thus increasing the economic performance of the tomato processing chain and decreasing the disposal problems.

### Acknowledgments

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS/CCCDI – UEFISCDI, project number PN-III-P2-2.1-BG-2016-0019, within PNCDI III.

### Disclosure statement

No potential conflict of interest was reported by the authors.

### Funding

This work was supported by a grant of the Romanian National Authority for Scientific Research and Innovation, CNCS/CCCDI – UEFISCDI, Grant number PN-III-P2-2.1-BG-2016-0019, within PNCDI III.

### ORCID

Violeta Nour [http://orcid.org/0000-0001-9904-0157](http://orcid.org/0000-0001-9904-0157)

### References

Altan, A., McCarthy, K. L., & Maskan, M. (2008). Evaluation of snack foods from barley-tomato pomace blends by extrusion processing. *Journal of Food Engineering*, 84, 231–242. doi:10.1016/j.jfoodeng.2007.05.014

Alves, A. B., Bragagnolo, N., Da Silva, M. G., Skibsted, L. H., & Orlien, V. (2012). Antioxidant effects of high-pressure processed minced chicken meat by industrial tomato products. *Food and Bioprocess Technology*, 90, 499–505. doi:10.1016/j.fbp.2011.10.004

Benakmoum, A., Abbeddou, S., Ammouche, A., Kefalas, P., & Gerasopoulos, D. (2008). Valorisation of low quality edible oil with

---

**Table 6.** Phenolic compounds in dried tomato waste (mg/kg).

| Phenolic compounds    | Dried tomato waste |
|-----------------------|--------------------|
| Gallic acid           | 17.1 ± 0.6         |
| Catechin hydrate      | nd                 |
| Vanillic acid         | 26.9 ± 1.1         |
| Chlorogenic acid      | 76.3 ± 2.8         |
| Caffeic acid          | nd                 |
| Syringic acid         | 2.2 ± 0.1          |
| Epicatechin           | nd                 |
| Coumaric acid         | 11.4 ± 0.5         |
| Ferulic acid          | nd                 |
| Sinapic acid          | nd                 |
| Salicylic acid        | 66.9 ± 2.7         |
| Rutin                 | 29.2 ± 1.1         |
| Ellagic acid          | 143.4 ± 5.9        |
| Myricetin             | 63.7 ± 2.2         |
| trans-Cinnamic acid   | nd                 |
| Quercetin             | nd                 |

**Table 6.** Compuestos fenólicos presentes en los desechos de tomate deshidratado (mg/kg).
Slimestad, R., & Verheul, M. J. (2009). Review of flavonoids and other phenolics from fruits of different tomato (Lycopersicon esculentum Mill.) cultivars. *Journal of the Science of Food and Agriculture, 89*, 1255–1270. doi:10.1002/jsfa.3605

Sogi, D. S., Sidhu, J. S., Arora, M. S., Garg, S. K., & Bawa, A. S. (2002). Effect of tomato seed meal supplementation on the dough and bread characteristics of wheat (PBW 343) flour. *International Journal of Food Properties, 5*, 563–571. doi:10.1081/JFP-120015492

Tommonaro, G., Poli, A., De Rosa, S., & Nicolaus, B. (2008). Tomato derived polysaccharides for biotechnological applications: Chemical and biological approaches. *Molecules, 13*, 1384–1398. doi:10.3390/molecules13061384

Toor, R. K., & Savage, G. P. (2005). Antioxidant activity in different fractions of tomatoes. *Food Research International, 38*, 487–494. doi:10.1016/j.foodres.2004.10.016

Varzaru, I., Untea, A. E., Martura, T., Olteanu, M., Panaite, T. D., Schitea, M., & Van, I. (2013). Development and validation of an RP-HPLC method for methionine, cystine and lysine separation and determination in corn samples. *Revista De Chimie-Bucharest, 67*(7), 673–679.

WPTC (The World Processing Tomato Council). (2015). World production estimate as of 15 October 2015. Retrieved January 10, 2017, from www.wptc.to/

Zuorro, A., Lavecchia, R., Medici, F., & Piga, L. (2013). Enzyme-assisted production of tomato seed oil enriched with lycopene from tomato pomace. *Food and Bioprocess Technology, 6*(12), 3499–3509. doi:10.1007/s11947-012-1003-6

Zuorro, A., Lavecchia, R., Medici, F., & Piga, L. (2014). Use of cell wall degrading enzymes for the production of high-quality functional products from tomato processing waste. *Chemical Engineering Transactions, 38*, 355–360. doi:10.3303/CET1438060