Nutritional composition and antioxidant activity of four tomato (*Lycopersicon esculentum* L.) farmer' varieties in Northeastern Portugal homegardens

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Abstract

The nutritional and antioxidant composition of four tomato Portuguese farmer' varieties widely cultivated in homegardens was determined. The analysed components included macronutrients, individual profiles of sugars and fatty acids by chromatographic techniques, hydrophilic antioxidants such as vitamin C, phenolics, flavonols and anthocyanins, and lipophilic antioxidants such as tocopherols, β-carotene and lycopene. Furthermore, the antioxidant activity was evaluated through DPPH scavenging activity, reducing power, β-carotene bleaching inhibition and TBARS formation inhibition. One of the four varieties, which is locally known as round tomato or potato tomato, proved to be the most powerful in antioxidant activity (EC_{50} values ≤ 1.63 mg/ml), phenolic compounds (phenolics 31.23 mg ClAE/g extract, flavonols 6.36 mg QE/g extract and anthocyanins 3.45 mg ME/g extract) and carotenoids (β-carotene 0.51 mg/100 g and lycopene 9.49 mg/100 g), while the so-called yellow tomato variety revealed interesting nutritional composition, including higher fructose (3.42 g/100 g), glucose (3.18 g/100 g), α-linolenic acid (15.53%) and total tocopherols (1.44 mg/100 g) levels. Overall, these farmer' varieties of garden tomato cultivated in the northeastern Portuguese region could contribute as sources of important antioxidants related to the prevention of chronic diseases associated to oxidative stress, such as cancer and coronary artery disease .

Keywords: Tomato; *Lycopersicon esculentum*; Farmers' varieties, Nutrients; Antioxidants; Antioxidant activity

1. Introduction

Tomato (*Lycopersicon esculentum* L.) is one of the most widely consumed vegetables, being the second most important vegetable crop worldwide. It is a key component in the so-called "Mediterranean diet", which is strongly associated with a reduced risk of chronic degenerative diseases (Agarwa and Aai, 2000; Rao and Agarwal, 1998).

Tomato is a major source of antioxidants contributing to the daily intake of a significant amount of these molecules. It is consumed fresh or as processed products such as canned tomato, sauce, juice ketchup, stews and soup (Lenucci et al., 2006). In fact, epidemiological studies have shown that consumption of raw tomato and its tomato-based products is associated with a reduced risk of cancer and cardiovascular diseases (Clinton, 1998; Giovannucci et al., 2002). This protective effect has been mainly attributed to its valuable bioactive components with antioxidant properties (Borguini and Torres, 2009).

Tomato antioxidants include carotenoids such as β-carotene, a precursor of vitamin A, and mainly lycopene, which is largely responsible for the red color of the fruit, vitamins such as ascorbic acid and tocopherols, and phenolic compounds such as flavonoids and hydroxycinnamic acid derivatives (Borguini and Torres, 2009; Clinton, 1998; Kotkov et al., 2009; Kotkov et al., 2011; Moco et al., 2006; Vallverdú-Queralt et al., 2011).

These compounds may play an important role inhibiting reactive oxygen species responsible for many important diseases, through free-radical scavenging, metal chelation, inhibition of cellular proliferation, and modulation of enzymatic activity and signal transduction pathways (Clinton, 1998; Crozier et al., 2009).

At present, there is a large number of tomato cultivars with a wide range of morphological and sensorial characteristics which determine their use. There are studies on nutritional value and antioxidant properties of tomato from different origins such as

Czech Republic (Kotkov et al., 2009, 2011), France (Gautier et al., 2008), Italy (Ilahy et al., 2011), Spain (Guil-Guerrero and Rebolloso-Fuentes, 2009; Vallverdú-Queralt et al., 2011) and Taiwan (Chang et al., 2006; Juroszek et al., 2009). Nevertheless, still now there are no reports on Portuguese varieties, moreover on Portuguese local varieties grown for a long time in homegardens.

In the past 30 years significant changes in farming systems and crop diversity have taken place in several rural areas of Portugal, particularly in the most northeastern region, known as Trás-os-Montes (Carvalho et al., 2010; Frazão-Moreira and Carvalho, 2009). New trends in rural lifestyles have highlighted the importance of a wide range of greens, particularly wild greens (Carvalho and Morales, 2010), and of local farmers' varieties grown since a long time, such as beans, cabbages, pimento and tomato.

At the same time, cultivation and consumption of vegetables have increased in the Iberian Peninsula which is due to the generalized use of greenhouses, allowing better control of nutrients available to plants and a global supply of these products. However, local populations from Trás-os-Montes still prefer to consume traditional vegetables (e.g. different farmer' varieties of tomato) which they find very tasty and healthy food, as they are grown using extensive farming techniques.

These farmer' varieties of tomato are thus being cultivated, but their nutritional composition has remained unreported until now. The main purpose of this study was to describe the nutritional value and the antioxidant activity of four non-analyzed tomato farmer 'varieties from Trás-os-Montes, Northeastern Portugal.

2. Materials and methods

2.1. Samples

Four common farmer' varieties of tomato widely cultivated in rural communities from Miranda do Douro, Trás-os-Montes, Northeastern Portugal, were chosen according morphological and sensorial characteristics which determine their use, as defined by our informants (**Table 1**).

Such varieties are known by their local vernacular name and used differently: "tomate amarelo" (yellow tomato), of intense yellow colour even when ripened, is consumed raw in salads; "tomate redondo or batateiro" (round tomato) is round-shaped like a potato and eaten raw or stewed with fish and meat or made in sauce; "tomate comprido" (long tomato) is similar to plum tomatoes and is mainly frozen and stored, to be available for use in cooking during winter; "tomate coração" (heart tomato), is a big, fleshy, juicy heart-shaped tomato that is mostly used for cooking and for preparing a traditional marmalade.

Tomato fruits at the red-ripe stage were hand harvested randomly in September 2010 from the middle of six plants of each of the four varieties, in selected homegardens of two villages in the studied area.

All plants from each tomato variety were grown under the same soil and climatic conditions and similar agricultural practices. The seeds were selected and kept by local farmers. The ripening stage for all samples was selected according to local consumers' criteria.

The edible portion of six fruits of each variety was prepared and used for analysis. The specimens of each variety were then lyophilised (FreeZone 4.5 model 7750031, Labconco, Kansas, USA), reduced to a fine dried powder (20 mesh), mixed to obtain a homogenate sample and kept at -20 ºC until further analysis.

2.2. Standards and Reagents

Acetonitrile 99.9%, *n*-hexane 95% and ethyl acetate 99.8% were of HPLC grade from Fisher Scientific (Lisbon, Portugal). The fatty acids methyl ester (FAME) reference standard mixture 37 (standard 47885-U), other individual fatty acid isomers, L-ascorbic acid, tocopherols (α-, β-, γ-, and δ-isoforms), sugars (D(-)-fructose, D(+)-glucose anhydrous, D(+)-melezitose hydrate, D(+)-sucrose), trolox (6-hydroxy-2,5,7,8-tetramethylchroman-2-carboxylic acid), chlorogenic acid, malvidin 3-glucoside and quercetin dehydrate standards were purchased from Sigma (St. Louis, MO, USA). Racemic tocol, 50 mg/ml, was purchased from Matreya (PA, USA). 2,2-Diphenyl-1-picrylhydrazyl (DPPH) was obtained from Alfa Aesar (Ward Hill, MA, USA). All other chemicals and solvents were of analytical grade and purchased from common sources. Water was treated in a Milli-Q water purification system (TGI Pure Water Systems, USA).

2.3. Nutritional composition

2.3.1. Nutritional value. The samples were analysed for chemical composition (moisture, proteins, fat, carbohydrates and ash) using the AOAC procedures (AOAC, 1995). The crude protein content (N × 6.25) of the samples was estimated by the macro-Kjeldahl method; the crude fat was determined by extracting a known weight of powdered sample with petroleum ether, using a Soxhlet apparatus; the ash content was determined by incineration at 600±15 ºC. Total carbohydrates were calculated by difference.

2.3.2. Sugars. Free sugars were determined by high performance liquid chromatography coupled to a refraction index detector (HPLC-RI) as described by Pinela et al. (2011), using melezitose as internal standard (IS). The equipment consisted of an integrated

system with a pump (Knauer, Smartline system 1000), degasser system (Smartline manager 5000), auto-sampler (AS-2057 Jasco) and a RI detector (Knauer Smartline 2300). Data were analysed using Clarity 2.4 Software (DataApex). The chromatographic separation was achieved with a Eurospher 100-5 NH_2 column (4.6 × 250 mm, 5 mm, Knauer) operating at 30ºC (7971 R Grace oven). The mobile phase was acetonitrile/deionized water, 70:30 (v/v) at a flow rate of 1 ml/min. The compounds were identified by chromatographic comparisons with authentic standards. Quantification was performed using the internal standard method and sugar contents were further expressed in g per 100 g of fresh weight (fw).

2.3.3. Fatty Acids. Fatty acids were determined by gas-liquid chromatography with flame ionization detection (GC-FID)/capillary column as described previously by the authors (Pinela et al., 2011). The analysis was carried out with a DANI model GC 1000 instrument equipped with a split/splitless injector, a flame ionization detector (FID at 260 ºC) and a Macherey-Nagel column (30 m × 0.32 mm ID × 0.25 µm d_f). The oven temperature program was as follows: the initial temperature of the column was 50 ºC, held for 2 min, then a 30ºC/min ramp to 125 ºC, 5ºC/min ramp to 160 ºC, 20ºC/min ramp to 180 ºC, 3ºC/min ramp to 200 ºC, 20ºC/min ramp to 220 ºC and held for 15 min. The carrier gas (hydrogen) flow-rate was 4.0 ml/min (0.61 bar), measured at 50 ºC. Split injection (1:40) was carried out at 250 ºC. Fatty acid identification was made by comparing the relative retention times of FAME peaks from samples with standards. The results were recorded and processed using CSW 1.7 software (DataApex 1.7) and expressed in relative percentage of each fatty acid.

2.4. Antioxidants composition

2.4.1. Tocopherols. Tocopherols content was determined following a procedure previously described by Barros et al. (2010), using tocol as IS. The analysis was carried out in the HPLC system described above connected to a fluorescence detector (FP-2020; Jasco) programmed for excitation at 290 nm and emission at 330 nm. The chromatographic separation was achieved with a Polyamide II normal-phase column (250 × 4.6 mm; YMC Waters) operating at 30ºC. The mobile phase used was a mixture of n-hexane and ethyl acetate (70:30, v/v) at a flow rate of 1 ml/min. The compounds were identified by chromatographic comparisons with authentic standards. Quantification was based on the fluorescence signal response, using the internal standard method, and tocopherols contents were further expressed in mg per 100 g of dry fresh (fw).

2.4.2. Ascorbic acid. Ascorbic acid was determined following a procedure previously described by the authors (Barros et al. 2010) with 2,6-dichloroindophenol, and measuring the absorbance at 515 nm (spectrophotometer Analytik Jena, Germany). Content of ascorbic acid was calculated on the basis of the calibration curve of authentic L-ascorbic acid (0.006-0.1 mg/ml), and the results were expressed as mg of ascorbic acid per 100 g of fresh weight (fw).

2.4.3. Carotenoids. β-carotene and lycopene were determined following a procedure previously described by the authors (Barros et al, 2010), measuring the absorbance at 453, 505, 645, and 663 nm. Contents were calculated according to the following equations: β-carotene (mg/100 ml) = $0.216 \times A_{663} - 1.220 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453}$; lycopene (mg/100 ml) = $-0.0458 \times A_{663} + 0.204 \times A_{645} - 0.304 \times A_{505} + 0.452 \times A_{453}$, and further expressed in mg per 100 g of dry weight (dw).

2.4.4. Phenolics. A fine dried powder (20 mesh; ~1g) stirring with 50 ml of methanol at 25 ºC at 150 rpm for 1 h and filtered through Whatman No. 4 paper. The residue was then extracted with one additional 50 ml portion of methanol. The combined methanolic extracts were evaporated at 35ºC under reduced pressure (rotary evaporator Büchi R-210), re-dissolved in methanol at 50 mg/ml, and stored at 4 ºC for further analysis of phenolics and antioxidant properties.

The extract sample concentrated at 0.625 mg/ml (250 µl) was mixed with HCl 0.1% in 95% ethanol (250 µl) and HCl 2% (4550 µl). After 15 min the absorbance was measured at 280, 360 and 520 nm. The absorbance (A) at 280 nm was used to estimate total phenolic content, $A_{360\ nm}$ was used to estimate flavonols, and $A_{520\ nm}$ was used to estimate anthocyanins (Mazza et al., 1999). Chlorogenic acid was used to calculate the standard curve (0.2-3.2 mM) and the results were expressed as mg of chlorogenic acid equivalents (ClAE) per g of extract. Quercetin was used to calculate the standard curve (0.2-3.2 mM) and the results were expressed as mg of quercetin equivalents (QE) per g of extract. Malvidin 3-glucoside was used to calculate the standard curve (0.1-2.3 mM) and the results were expressed as mg of malvidin 3-glucoside equivalents (ME) per g of extract.

2.6. Evaluation of antioxidant activity

2.6.1. DPPH radical-scavenging activity. This methodology was performed using an ELX800 Microplate Reader (Bio-Tek). The reaction mixture in each one of the 96-wells consisted of one of the different concentrations of the extracts (30 µl) and aqueous methanolic solution (80:20 v/v, 270 µl) containing DPPH radicals (6×10^{-5} mol/l). The mixture was left to stand for 60 min in the dark. The reduction of the DPPH radical was

determined by measuring the absorption at 515 nm (Pinela et al., 2011). The radical scavenging activity (RSA) was calculated as a percentage of DPPH discolouration using the equation: % RSA = $[(A_{DPPH}-A_S)/A_{DPPH}] \times 100$, where A_S is the absorbance of the solution when the sample extract has been added at a particular level, and A_{DPPH} is the absorbance of the DPPH solution. The extract concentration providing 50% of radicals scavenging activity (EC_{50}) was calculated from the graph of RSA percentage against extract concentration. Trolox was used as standard.

2.6.2. Reducing power. This methodology was performed using the Microplate Reader described above. The different concentrations of the extracts (0.5 ml) were mixed with sodium phosphate buffer (200 mmol/l, pH 6.6, 0.5 ml) and potassium ferricyanide (1% w/v, 0.5 ml). The mixture was incubated at 50 ºC for 20 min, and trichloroacetic acid (10% w/v, 0.5 ml) was added. The mixture (0.8 ml) was poured in the 48-wells, as also deionised water (0.8 ml) and ferric chloride (0.1% w/v, 0.16 ml), and the absorbance was measured at 690 nm (Pinela et al., 2011). The extract concentration providing 0.5 of absorbance (EC_{50}) was calculated from the graph of absorbance at 690 nm against extract concentration. Trolox was used as standard.

2.6.3. Inhibition of β-carotene bleaching. A solution of β-carotene was prepared by dissolving β-carotene (2 mg) in chloroform (10 ml). Two millilitres of this solution were pipetted into a round-bottom flask. After the chloroform was removed at 40ºC under vacuum, linoleic acid (40 mg), Tween 80 emulsifier (400 mg), and distilled water (100 ml) were added to the flask with vigorous shaking. Aliquots (4.8 ml) of this emulsion were transferred into different test tubes containing different concentrations of the extracts (0.2 ml). The tubes were shaken and incubated at 50ºC in a water bath. As

soon as the emulsion was added to each tube, the zero time absorbance was measured at 470 nm (Pinela et al., 2011). β-Carotene bleaching inhibition was calculated using the following equation: (β-carotene content after 2h of assay/initial β-carotene content) × 100. The extract concentration providing 50% antioxidant activity (EC_{50}) was calculated by interpolation from the graph of β-carotene bleaching inhibition percentage against extract concentration. Trolox was used as standard.

2.6.4. Inhibition of lipid peroxidation using thiobarbituric acid reactive substances (TBARS). Brains were obtained from porcine (*Sus scrofa*), dissected and homogenized with a Polytron in ice-cold Tris–HCl buffer (20 mM, pH 7.4) to produce a 1:2 (w/v) brain tissue homogenate which was centrifuged at 3000*g* (Centorion K24OR refrigerated centrifuge) for 10 min. An aliquot (0.1 ml) of the supernatant was incubated with the different concentrations of the extracts (0.2 ml) in the presence of $FeSO_4$ (10 μM; 0.1 ml) and ascorbic acid (0.1 mM; 0.1 ml) at 37 ºC for 1 h. The reaction was stopped by the addition of trichloroacetic acid (28% w/v, 0.5 ml), followed by thiobarbituric acid (TBA, 2%, w/v, 0.38 ml), and the mixture was then heated at 80 ºC for 20 min. After centrifugation at 3000g for 10 min to remove the precipitated protein, the colour intensity of the malondialdehyde (MDA)-TBA complex in the supernatant was measured by its absorbance at 532 nm (Pinela et al., 2011). The inhibition ratio (%) was calculated using the following formula: Inhibition ratio (%) = [(A – B)/A] x 100%, where A and B were the absorbance of the control and the compound solution, respectively. The extract concentration providing 50% lipid peroxidation inhibition (EC_{50}) was calculated from the graph of TBARS inhibition percentage against extract concentration. Trolox was used as standard.

2.7. Statistical analysis

For each sample three extracts were obtained and all the assays were carried out in triplicates. The results are expressed as mean values and standard deviation (SD). The results were analyzed using one-way analysis of variance (ANOVA) followed by Tukey's HSD test with $\alpha = 0.05$. This treatment was carried out using SPSS v. 16.0 program.

3. Results and discussion

3.1. Nutritional composition

The results of the macronutrients composition and energetic value obtained for the studied tomato varieties are shown in **Table 2**. Moisture ranges between 90.63 g/100 g fw in the yellow tomato sample and 93.70 g/100 g fw in the long tomato. The highest levels of protein and ash were found in the yellow tomato (0.61 and 0.74 g/100 g fw, respectively). Otherwise, this sample gave the lowest fat levels (0.03 g/100 g fw). Carbohydrates were the most abundant macronutrients and the highest levels were also found in the yellow variety (7.99 g/100 g fw). This sample also gave the highest energetic value (34.67 kcal/100 g fw). Tomato varieties have high moisture, proteins and carbohydrates contents, in contrast to low fat levels, which make them suitable to incorporate low caloric diets. These proportions are in agreement to the proximate composition of Spanish tomato varieties reported by Guil-Guerrero and Rebolloso-Fuentes (2009). Nevertheless, those samples revealed higher fat levels but lower carbohydrates content and energetic value than the Portuguese samples herein studied.

Sugars are abundant carbohydrates in the samples and followed the order fructose > glucose >> sucrose (**Table 2**). Once more, the yellow tomato revealed the highest total

sugars content (6.62 g/100 g fw), with the highest levels of fructose (3.42 g/100 g fw), glucose (3.18 g/100 g fw) and sucrose (0.02 g/100 g fw). These sugars are the major source of energy for metabolism (Bernal et al., 2010).

The results of the main fatty acids found in the studied tomato varieties, as also their saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) percentages are shown in **Table 3**. Up to twenty-four fatty acids were detected in most of the samples. The major fatty acid found was linoleic acid (C18:2n6c). Other abundant PUFA was α-linolenic acid (C18:3n3), and PUFA levels were higher than MUFA and SFA in all the samples. The studied varieties also revealed the SFA palmitic acid (C16:0) and the MUFA oleic acid (C18:1n9) as major fatty acids. This profile is similar to the one described for Spanish tomato varieties, but with higher C18:3n3 levels (Guil-Guerrero and Rebolloso-Fuentes, 2009). The long tomato gave the highest PUFA (58%) and MUFA (18%) percentages, with the highest levels C18:2n6c (52%) and C18:1n9 (17%). Otherwise, the yellow tomato showed the highest levels of SFA (33%) mainly C16:0 (21%), but also the highest levels of C18:3n3 (16%).

Fatty acids are important as nutritional substances in living organisms. Long-chain PUFA, especially those of the n-3 series, such as 18:3n3, are essential for human metabolism and have many beneficial effects including the prevention of a number of diseases, such as coronary heart diseases, inflammation, autoimmune disorders, hypertension, hypotriglyceridemic effect, etc. (Bernal et al., 2010).

3.2. Antioxidants composition

Antioxidants such as vitamins, carotenoids and phenolics were determined and the results are provided in **Table 4**. Ascorbic acid was the most abundant antioxidant in all the samples, and the highest concentration was found in the sample of the so-called

heart tomato (18.56 mg/100 g fw). The values found in the present study were similar to the ones reported on varieties from Italy (Ilahy et al., 2011) and Taiwan (Juroszek et al., 2009) (both in the order of 20 mg/100 g fw), but lower than the values found in Czech Republic (21.7-25.8 mg/100 g fw, Kotkov et al., 2011) and Spanish (39-163 mg/100 g fw; Guil-Guerrero and Rebolloso-Fuentes, 2009) varieties. The role of ascorbic acid in the prevention of diseases related to oxidative damage occurs due to its ability to neutralize the action of free radicals in the biological systems (Borguini and Torres, 2009). This hydrophilic antioxidant is abundant in many fruits and is the most common in the majority of them, when compared with the presence of lipophilic antioxidants such as vitamin E (tocopherols).

The yellow tomato variety presented the highest content of tocopherols (1.44 mg/100 g fw) with the highest levels of α- (0.88 mg/100 g fw) and γ- (0.53 mg/100 g fw) isoforms. β-Carotene was found in lower amounts than tocopherols, while lycopene was present in higher concentrations; the highest levels of carotenoids were observed in the sample from round tomato (0.51 and 9.49 mg/100 g fw for β-carotene and lycopene, respectively). The β-carotene levels found in the studied Portuguese farmer' varieties were similar to the concentration reported on varieties from Italy (Ilahy et al., 2011) and Taiwan (Juroszek et al., 2009) (~0.5 mg/100 g fw). Nevertheless, lycopene values observed in the studied samples were higher than the ones described for fresh and lyophilized samples from Taiwan (3 and 2 mg/100 g fw, respectively; Chang et al., 2006), but slightly lower than in Italian varieties (~10 mg/100 g fw; Ilahy et al., 2011). Lycopene is a carotenoid compound wildly present in tomato and dietary intake of food containing lycopene has been shown to be related to decreased risk of chronic diseases, such as cancer and cardiovascular disease (Agarwal and Rao, 2000). The potential as an

antioxidant is related to its capacity to scavenge singlet oxygen and radical peroxyl (Borguini and Torres, 2009).

All the differences observed in the antioxidant contents of tomato varieties are related to genotype, but also to several factors such as the ripening stage, cultivation practices (water availability, mineral nutrients), and climatic environment (mostly light and temperature) (Dumas et al., 2003).

Some non-essential dietary compounds such as phenolics, flavonols and anthocyanins were also determined and the highest levels were found in the farmer' variety known as long tomato (31.23 mg ClAE/g extract, 6.36 mg QE/g extract and 3.45 mg ME/g extract, respectively; **Table 4**). The main phenolic compounds found in tomato are the flavonols quercetin and kaempferol (mainly in conjugated form attached to sugar molecules) and the hydroxycinnamic acids, particularly the caffeic and chlorogenic acids (Vallverdú-Queralt et al., 2011). Phenolic compounds have been associated with the inhibition of atherosclerosis and cancer due to their ability to chelate metals, inhibit lipid peroxidation and scavenge free radicals (Borguini and Torres, 2009).

3.3. Antioxidant activity

The studied tomato Portuguese farmer' varieties demonstrated capacity to scavenge free radicals such as DPPH, high reducing power and capacity to inhibit lipid peroxidation in a β-carotene-linoleate system, after neutralization of the linoleate-free radical and other free radicals formed in the system which attack the highly unsaturated β-carotene models, and in brain cells homogenates avoiding the formation of TBARS.

The round tomato gave the best results in all the antioxidant activity assays (DPPH scavenging activity, reducing power, β-carotene bleaching inhibition and TBARS inhibition) with EC_{50} values ≤ 1.63 mg/ml. This is in agreement to its highest levels of

antioxidants such as phenolics, flavonols, anthocyanins, β-carotene, lycopene, β-tocopherol and δ-tocopherol. Otherwise, the farmer'variety yellow tomato revealed the lowest antioxidant properties (EC_{50} values ≤ 2.11 mg/ml) and also the lowest phenolics, flavonols, anthocyanins and lycopene.

As far as we know, the antioxidant potential of the studied varieties was not previously reported.

4. Conclusions

Current dietary guidelines to combat chronic diseases, including cancer and coronary artery disease, recommend increased intake of plant foods, including fruits and vegetables, which are rich sources of antioxidants, and many studies have shown that a close relation exists between the intake of vegetables and cancer prevention (Chang et al., 2006). Therefore, tomato as one of the most versatile and widely-used food plants could play an important role in human diet. Portuguese tomato farmers'varieties are rich sources in antioxidant compounds such as ascorbic acid, carotenoids, in particular lycopene, and phenolic compounds. One of the studied varieties, the so-called round tomato proved to be the most powerful in antioxidant activity, phenolic compounds and carotenoids, while the variety locally known as yellow tomato revealed interesting nutritional composition, including higher fructose, glucose, α-linolenic acid and total tocopherols levels.

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Table 1. Several morphologic characteristics and description of four different tomato Portuguese farmer' varieties: yellow tomato (Amarelo), round tomato (Batateiro), long tomato (Comprido) and heart tomato (Coração).

	Amarelo	Batateiro	Comprido	Coração
Predominant fruit shape	flattened (oblate)	high rounded potato-shaped	ellipsoid (plum-shaped)	heart-shaped
Fruit size	intermediate (5.1-8 cm)	small (3-5 cm)	small (3-5 cm)	very large (>10 cm)
Fruit weight (average)	190 g	116 g	132 g	465 g
Exterior colour of mature fruit	yellow	red	orange/red	red/pink
Flesh colour of pericarp	yellow	red	orange/green	pink/red
Fruit cross-sectional shape	irregular	irregular	angular	irregular
Fruit blossom end shape	indented	flat	pointed	pointed
Fruit firmness	firm	intermediate	firm	soft
Fruit shoulder shape	strongly depressed	moderately depressed	flat	slightly depressed
Jointed pedicel	present	present	present	present
Number of locules	multilocular	multilocular	trilocular	multilocular
Seeds number	intermediate	hight	hight	small

Average of 10 fruits from different plants

Table 2. Macronutrients, energetic value and individual sugars composition of four different tomato Portuguese farmer'varieties: yellow tomato (Amarelo), round tomato (Batateiro), long tomato (Comprido) and heart tomato (Coração).

	Amarelo	Batateiro	Comprido	Coração
Moisture (g/100 g fw)	90.63 ± 0.46	92.21 ± 0.77	93.70 ± 1.02	92.76 ± 1.54
Ash (g/100 g fw)	0.74 ± 0.02 a	0.63 ± 0.03 b	0.59 ± 0.03 b	0.54 ± 0.00 c
Proteins (g/100 g fw)	0.61 ± 0.01 a	0.41 ± 0.00 b	0.40 ± 0.01 b	0.42 ± 0.00 b
Fat (g/100 g fw)	0.03 ± 0.00 d	0.11 ± 0.01 c	0.17 ± 0.01 a	0.13± 0.02 b
Carbohydrates (g/100 g fw)	7.99 ± 0.01 a	6.63 ± 0.02 b	5.14 ± 0.02 d	6.14 ± 0.01 c
Energy (kcal/100 g fw)	34.67 ± 0.09 a	29.17 ± 0.12 b	23.72 ± 0.10 d	27.44 ± 0.05 c
Fructose	3.42 ± 0.20 a	3.13 ± 0.30 ba	2.15 ± 0.01 c	2.71 ± 0.00 b
Glucose	3.18 ± 0.22 a	2.69 ± 0.27 b	1.74 ± 0.01 d	2.22 ± 0.01 c
Sucrose	0.02 ± 0.00 a	0.01 ± 0.00 b	0.02 ± 0.00 a	0.02 ± 0.00 a
Total sugars (g/100 g fw)	6.62 ± 0.41 a	5.83 ± 0.57 ba	3.91 ± 0.02 c	4.95 ± 0.01 b

In each row, different letters mean significant differences (p<0.05).

Table 3. Fatty acids composition (percentage) of four different tomato Portuguese farmer' varieties: yellow tomato (Amarelo), round tomato (Batateiro), long tomato (Comprido) and heart tomato (Coração).

	Amarelo	Batateiro	Comprido	Coração
C6:0	0.01 ± 0.00	0.02 ± 0.00	0.04 ± 0.00	0.05 ± 0.01
C8:0	0.10 ± 0.01	0.09 ± 0.01	0.03 ± 0.00	0.02 ± 0.00
C10:0	0.07 ± 0.01	0.06 ± 0.01	0.02 ± 0.01	0.01 ± 0.00
C12:0	0.15 ± 0.02	0.11 ± 0.00	0.04 ± 0.00	0.05 ± 0.00
C14:0	0.93 ± 0.10	0.62 ± 0.01	0.32 ± 0.01	0.57 ± 0.01
C15:0	0.15 ± 0.00	0.11 ± 0.00	0.08 ± 0.01	0.11 ± 0.01
C16:0	20.53 ± 0.91	19.31 ± 0.18	15.96 ± 0.10	19.05 ± 0.04
C16:1	0.25 ± 0.00	0.32 ± 0.01	0.29 ± 0.00	0.28 ± 0.00
C17:0	0.33 ± 0.03	0.25 ± 0.01	0.18 ± 0.01	0.27 ± 0.00
C18:0	6.34 ± 0.03	5.47 ± 0.07	6.36 ± 0.31	5.39 ± 0.11
C18:1n9	10.60 ± 1.24	12.61 ± 0.23	17.45 ± 0.86	12.97 ± 0.36
C18:2n6	39.80 ± 1.85	46.33 ± 0.40	52.05 ± 0.64	48.19 ± 0.15
C18:3n3	15.53 ± 1.41	11.41 ± 0.42	5.55 ± 0.50	10.08 ± 0.34
C20:0	1.26 ± 0.11	0.80 ± 0.02	0.61 ± 0.02	0.83 ± 0.01
C20:1	0.12 ± 0.00	0.12 ± 0.01	0.05 ± 0.00	0.09 ± 0.01
C20:2	0.06 ± 0.01	0.03 ± 0.00	0.02 ± 0.00	0.04 ± 0.00
C20:4n6	0.06 ± 0.00	0.04 ± 0.00	0.01 ± 0.00	0.03 ± 0.00
C20:3n3+C21:0	0.20 ± 0.01	0.09 ± 0.01	0.08 ± 0.00	0.14 ± 0.02
C20:5n3	0.03 ± 0.00	0.05 ± 0.01	0.04 ± 0.01	0.06 ± 0.01
C22:0	0.82 ± 0.12	0.55 ± 0.00	0.31 ± 0.00	0.66 ± 0.01
C22:1n9	0.03 ± 0.00	0.03 ± 0.00	0.01 ± 0.00	0.01 ± 0.00
C22:2	0.10 ± 0.00	0.07 ± 0.00	0.03 ± 0.00	0.08 ± 0.01
C23:0	1.52 ± 0.19	0.78 ± 0.02	0.16 ± 0.01	0.24 ± 0.03
C24:0	1.01 ± 0.07	0.73 ± 0.01	0.45 ± 0.01	0.76 ± 0.02
Total SFA	33.22 ± 1.68 a	28.91 ± 0.26 b	24.57 ± 0.29 c	27.93 ± 0.09 b
Total MUFA	11.00 ± 1.24 c	13.08 ± 0.28 b	17.66 ± 0.86 a	13.45 ± 0.37 b
Total PUFA	55.78 ± 0.43 b	58.01 ± 0.02 a	57.77 ± 1.14 a	58.63 ± 0.46 a

Caproic acid (C6:0); Caprylic acid (C8:0); Capric acid (C10:0); Lauric acid (C12:0); Myristic acid (C14:0); Pentadecanoic acid (C15:0); Palmitic acid (C16:0); Palmitoleic

acid (C16:1); Heptadecanoic acid (C17:0); Stearic acid (C18:0); Oleic acid (C18:1n9c); Linoleic acid (C18:2n6c); α-Linolenic acid (C18:3n3); Arachidic acid (C20:0); *cis*-11-Eicosenoic acid (C20:1c); *cis*-11,14-Eicosadienoic acid (C20:2c); Arachidonic acid (C20:4n6); *cis*-11,14,17-Eicosatrienoic acid and Heneicosanoic acid (C20:3n3+C21:0); cis-5,8,11,14,17-Eicosapentaenoic acid (C20:5n3); Erucic acid (C22:1n9); *cis*-13,16-Docosadienoic acid (C22:2); Behenic acid (C22:0); Tricosanoic acid (C23:0); Lignoceric acid (C24:0).

SFA- saturated fatty acids; MUFA- monounsaturated fatty acids; PUFA- polyunsaturated fatty acids. In each row different letters mean significant differences ($p<0.05$).

Table 4. Antioxidants composition of four different tomato Portuguese farmer' varieties: yellow tomato (Amarelo), round tomato (Batateiro), long tomato (Comprido) and heart tomato (Coração).

	Amarelo	Batateiro	Comprido	Coração
α-tocopherol	0.88 ± 0.03 a	0.68 ± 0.01 b	0.59 ± 0.01 c	0.68 ± 0.02 b
β-tocopherol	0.02 ± 0.00 b	0.03 ± 0.00 a	0.03 ± 0.00 a	0.03 ± 0.00 a
γ-tocopherol	0.53 ± 0.04 a	0.43 ± 0.01 b	0.40 ± 0.01 b	0.45 ± 0.04 b
δ-tocopherol	0.01 ± 0.00 b	0.02 ± 0.00 a	0.01 ± 0.00 b	0.02 ± 0.01 a
Total tocopherols (mg/100 g fw)	1.44 ± 0.07 a	1.16 ± 0.02 b	1.02 ± 0.01 c	1.18 ± 0.04 b
Vitamin C (mg/100 g fw)	16.03 ± 0.38 c	10.86 ± 0.09 d	16.50 ± 0.03 b	18.56 ± 0.04 a
β-carotene (mg/100 g fw)	0.42 ± 0.02 b	0.51 ± 0.03 a	0.30 ± 0.01 c	0.43 ± 0.02 b
Lycopene (mg/100 g fw)	5.02 ± 0.09 c	9.49 ± 0.18 a	8.10 ± 0.10 b	9.22 ± 0.15 a
Phenolics (mg ClAE/g extract)	21.34 ± 1.16 c	31.23 ± 1.15 a	24.48 ± 1.67 b	24.92 ± 3.04 b
Flavanols (mg QE/g extract)	3.06 ± 0.84 c	6.36 ± 0.28 a	4.05 ± 0.28 b	3.44 ± 0.45 cb
Anthocyanins (mg ME/g extract)	0.23 ± 0.08 d	3.45 ± 0.23 a	1.36 ± 0.26 b	1.02 ± 0.13 c

nd- not detected. In each row different letters mean significant differences (p<0.05).

Table 4. Antioxidant properties (EC_{50} values) of four different tomato Portuguese farmer' varieties: yellow tomato (Amarelo), round tomato (Batateiro), long tomato (Comprido) and heart tomato (Coração).

	Amarelo	Batateiro	Comprido	Coração
DPPH scavenging activity (mg/ml)	0.75 ± 0.01 a	0.55 ± 0.02 c	0.69 ± 0.01 b	0.65 ± 0.04 b
Reducing power (mg/ml)	2.04 ± 0.01 a	1.63 ± 0.06 d	1.82 ± 0.04 c	1.91 ± 0.05 b
β-carotene bleaching inhibition (mg/ml)	2.11 ± 0.24 a	0.89 ± 0.11 c	1.60 ± 0.16 b	1.49 ± 0.15 b
TBARS inhibition (mg/ml)	1.82 ± 0.35 a	1.34 ± 0.45 b	1.58 ± 0.17 ba	1.71 ± 0.41 ba

In each row different letters mean significant differences ($p<0.05$).