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Effect of cultivation method and processing on total polyphenols content and antioxidant capacity of tomatoes (Solanum lycopersicum)

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ABSTRACT

Introduction: Tomato is an important dietary source of polyphenols. Factors such as cultivation method and heat can affect its composition. The objective of this study was to determine changes of polyphenol content and antioxidant capacity in tomatoes obtained from different production method (organic vs. conventional), before and after being cooked.

Methods: Total polyphenols and antioxidant capacity were measured in fresh and processed tomatoes from two cultivation methods, using spectrophotometric techniques.

Results: Antioxidant capacity was higher ($p<0.05$) for fresh and processed samples of organic tomatoes compared with conventional ones (organic 17,82 mg Fe^{+2}/g > conventional 15,39 mg Fe^{+2}/g). No significant difference in polyphenol content according to method of cultivation was found (organic 3,8 µg GAE/g > conventional 3,2 µg GAE/g). Measured parameters were not significantly affected by physical and mechanical processing in tomatoes from both cultivation methods.

Discussion: A tendency towards better phytochemical properties in organic tomatoes were found in our study, which is consistent with existing literature. Antioxidant compounds in organic samples appear to be more resistant to processing.

Conclusion: It is necessary to deepen the study of organic and conventional tomatoes, in order to get more evidence on its nutritional quality.

KEYWORDS

Antioxidants – Phytochemicals – Food quality – Agricultural crops – Organic food.

ABBREVIATIONS

CFT: Conventional Fresh Tomato.

OFT: Organic Fresh Tomato.

CPT: Conventional Processed Tomato.

OPT: Organic Processed Tomato.

INTRODUCTION

Tomato (*Solanum lycopersicum*) is the second most consumed vegetable in the world[1]. A great proportion of it is used by industry to produce tomato puree, crushed tomatoes, canned tomatoes and tomato extract[2]. Also, it is a fruit with great interest for human nutrition, because of its content of vitamins, minerals and antioxidant compounds, such as carotenoids, mainly lycopene, ascorbic acid and polyphenols[3,4].

One of the most important functions of these reducing compounds is to capture free radicals, leading to antioxidant

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capacity[5]. From this perspective, they have a beneficial effect on health, as they protect human organism against oxidative stress, contributing to chemoprevention of several human pathologies, including coronary heart disease and cancer[6,7,8].

Recently, there is a growing interest and demand for organic products, because of the perception that they are healthier and tastier, with a favorable impact on health and environment[9]. Although organic tomato is proposed as a better food, studies on this matter are not conclusive[10].

Tomato content of polyphenols may be influenced by multiple factors, including agricultural method (organic or conventional). In this sense, synthetic fertilizers, usually used in conventional crops, promote plant development, but not necessarily the production of secondary metabolites. In addition, these compounds are produced as defense against stress situations, such as plagues, which can explain their higher concentration in the absence of pesticides[11].

In addition, industrial and domestic transformation and storage of tomato products can cause qualitative and quantitative variations on polyphenol content, which determine the antioxidant capacity of these products[12]. Food processing can increase or decrease the antioxidant capacity, with conservation by heat affecting natural food antioxidants[13].

Therefore, the **objective** of this study was to determine the changes of polyphenol content and antioxidant capacity of tomatoes obtained from different forms of production (organic vs. conventional), before and after being processed to evaluate, additionally, their heat resistance.

METHODS

Obtaining the samples

Selection of organic and conventional tomatoes: a random sample of 4 fruits from five stands of representative food providers of the region was selected:

- Organic tomatoes: Agroecological trade Fair (n = 20), a socio-productive commerce network formed by local families, cooperatives and institutions, as well as projects promoted by Universidad Nacional de Córdoba.
- Conventional tomatoes: Abasto´s Market from Córdoba City in the province of Córdoba, Argentina (n=20), which is the main fruit and vegetable distribution center of the region.

Subsequently a subsample of 1 Kg of each crop (conventional and organic) was taken for processing.

Half of each sample (500 g) was kept under refrigeration for determinations in fresh tomatoes. For the production of artisanal preserves, 500 g of organic and conventional tomatoes were used, which were washed, crushed and placed in a sterile container, that was boiled for 30 minutes at 100 °C.

Sample preparation

Fresh tomatoes obtained from each type of culture, as well as artisanal preserves were mechanically homogenized and the samples (tomato homogenate) were macerated with 50% ethyl alcohol solution and incubated in oven at 50°C for 30 minutes. Subsequently, samples were centrifuged at maximum revolutions and the supernatant obtained was stored at -20 ° C until its use.

Determination of Total Polyphenols

Total polyphenols were measured in these samples (25 µL) incubated with the 2 N Folin-Ciocalteu reagent (25 µL), water (150 µL) and a saturated sodium bicarbonate solution (50 µL), for 30 min in darkness at 37°C. Absorbance was measured at 750 nm and results were calculated from a standard curve of Gallic Acid (0.01- 18.75 µg) and expressed as µg GAE (Gallic acid equivalent)/g of tomato[14].

Determination of antioxidant capacity

The ability of samples to reduce Fe^{+3} to Fe^{+2} was determined by reaction with trypiridil triazine (FRAP assay)[15]. Samples (20 µL) were treated with 224 µL of 300 mM acetate buffer pH:3.6; 28 µL of a 10 mM solution of Ferric Sulfate (Fe_2 (SO_4) $3H_2O$); and 28 µL of 10 mM 2,4,6-tripyridyl-s-triazine in 40 mM HCl. Absorbance was measured at 593 nm after 10 minutes of reaction. Readings were compared with a standard calibration curve performed with 0.016 to 0.53 mg of Ferrous Sulfate ($FeSO_4.7H_2O$). Results were expressed as mg of Fe^{2+}/g of tomato.

Statistical analysis

Data were expressed as means ± standard errors from at least three separate experiments.

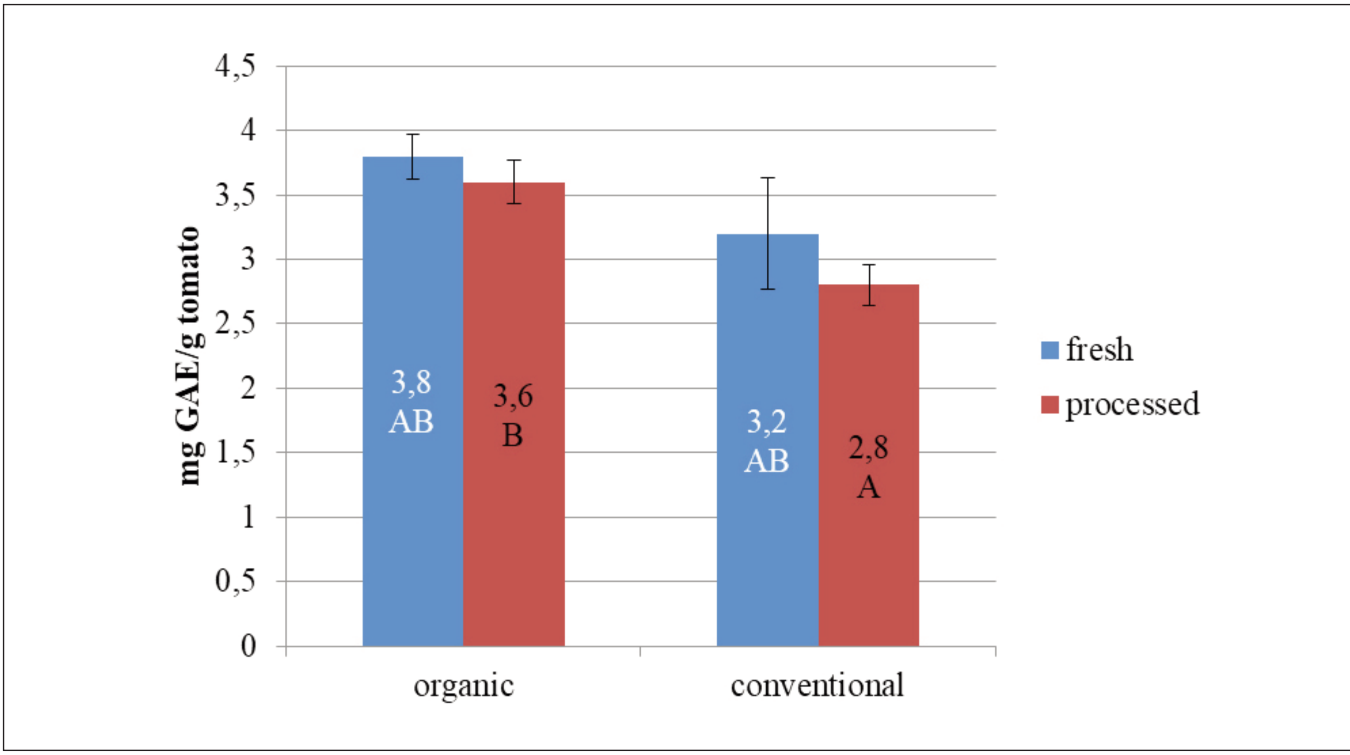
ANOVA models were used for mean comparisons followed by the Fisher test to compare different samples ($p<0.05$). Analyses were performed with the InfoStat 2018 software[16].

RESULTS

In our study, tomatoes obtained from organic crops showed a higher concentration of polyphenols (3,8 µg GAE/g) than tomatoes from conventional crops (3,2 µg GAE/g) (Figure 1). Antioxidant capacity, expressed as mg of Fe+2/g of tomato, was also higher in organic tomatoes (17,82 mg Fe+2/g), being this difference statistically significant compared to the conventional ones (15,39 mg Fe+2/g) (Figure 2).

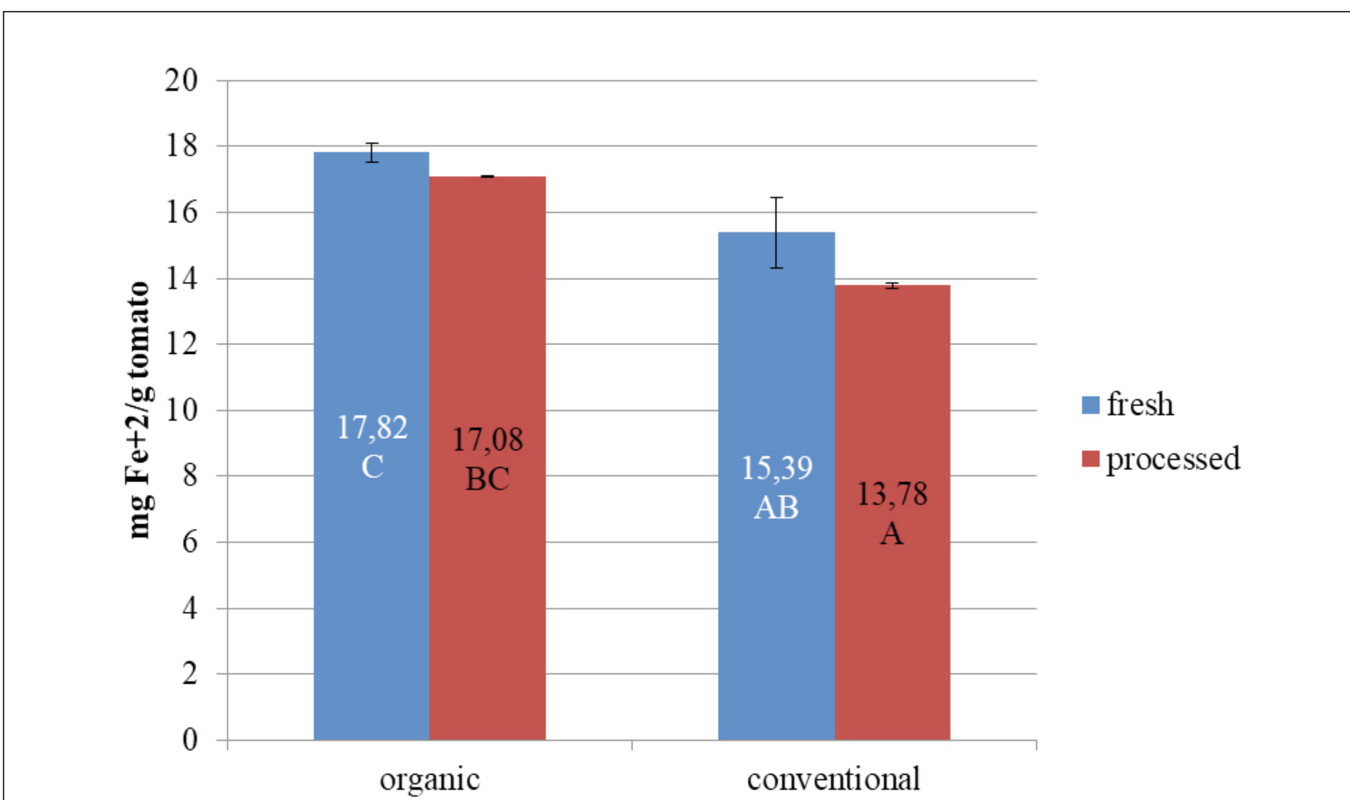
When tomatoes were processed, the levels of both total polyphenols and antioxidant capacity decrease, being the conventional tomatoes the ones that suffer a more accentuated declining (Figures 1 and 2). These results were not statistically significant for the latter.

Figure 1. Content of total Reducing compounds pre and post-treatment of tomatoes as obtained from organic and conventional crops.



Results were expressed in mg GAE/g of tomato (mean +/- SD of n=3). Different letters indicate statistically significant differences (p<0.05).

Figure 2. Antioxidant capacity pre and post-treatment of tomatoes as obtained from organic and conventional crops.



The results were expressed in mg of Fe^{+2} / g of tomato (mean +/- SD of n=3). Different letters indicate statistically significant differences (p<0.05).

DISCUSSION

Total Polyphenols

Though interest in organic foods has been increasing, studies on their nutritional quality compared to conventional foods are contradictory. Most of the evidence indicates that there is a higher content of secondary metabolites and other nutrients when the food is grown in the absence of agrochemicals. This may be attributed to the fact that fertilizers are not applied to organic crops, which exposes plants to a certain level of stress that could lead to a greater synthesis of these compounds as a defense mechanism[10,17]. However other studies have not found differences attributable to the type of crop[18]. In this study, measurements performed on fresh tomatoes from conventional (CFT) and organic crops (OFT) showed a higher concentration of polyphenols in the organic ones, although this difference was not statistically significant.

On the other hand, when processing the samples for the elaboration of artisanal preserves, the content of total polyphenols in tomatoes from both cultivation methods decreased. The decrease was higher in tomatoes from conventional crops (CPT), being the organic ones (OPT) significantly higher in these compounds, in agreement with results obtained in other studies[19]. This may be attributed to the fact that each sample contains reducing compounds that differ in their chemical structure, and consequently have different resistance to heat[20]. In this sense antioxidant compounds, such as ascorbic acid and some carotenoids are very sensitive to heat, while polyphenols and flavonoids are more stable at high temperatures[21]. This is important considering that some agrochemicals, such as glyphosate, interfere with the steps of secondary compound biosynthesis mainly by inhibiting 5-enolpyruvyl shikimate-3-phosphate (EPSP) synthase, blocking the synthesis of all cinnamate derivatives. Therefore, the relationship between thermostable and thermolabile compounds may be different in conventional crops where these herbicides are used[22]. Other investigations found stronger declines after processing the samples and indicate that organically grown vegetables suffered more deleterious consequences than conventional vegetables[23].

Although heat treatment is considered the main cause of natural antioxidants decrease in food, it can also induce the development of compounds with antioxidant properties, such as those that occur during Maillard reaction[24]. A study reports that certain thermal treatments increase the content of polyphenols, possibly because it causes the liberation of compounds contained in fruits and vegetables vacuoles, in addition to cell breakdown and denaturation of oxidative and hydrolytic enzymes, capable of degrading polyphenols[20].

Antioxidant capacity

Total antioxidant capacity was significantly higher in organic fresh and processed tomatoes than in conventional tomatoes. Results are consistent with studies carried out by other authors[25]. This may be attributed to the higher content of total polyphenols in organic tomatoes described above, considering that these compounds greatly contribute to total antioxidant capacity[26].

Regarding processed tomatoes, we observed that the organic ones had significantly higher antioxidant capacity than the conventional ones. Contrarily, the study performed by Drakou et al.[24] found that after processing tomatoes there was no significant difference between the two cultivation methods.

Respect to the effect of mechanical and thermal processing on antioxidant capacity, both in organic and conventional tomatoes, they presented a lower post-treatment antioxidant capacity with respect to the fresh fruit; however, this decrease was not statistically significant. Kelebek et al.[27] found a significantly higher decrease in antioxidant capacity during processing.

Total antioxidant capacity responds to many compounds contained in vegetables, which have variable thermal resistance. The most sensitive to heat are the hydrophilic fractions, represented mainly by vitamin C. The loss of vitamin C by thermal processing would explain the slight decrease in antioxidant capacity observed in processed fruits. However, the decrease is not prominent since, for the case of tomato, the main responsible for its antioxidant power are polyphenols, compounds with a greater thermal stability, as we previously described[28]. In this sense, a positive correlation was found between the content of total reducing compounds and total antioxidant capacity ($r=0.8$), indicating that the total antioxidant capacity observed in the samples is mainly due to the content of the reducing compounds studied. Correlation between antioxidant capacity and active principles was previously reported for many vegetables and would explain the similar behavior of the post-treatment variables in the present work[29].

CONCLUSION

The present investigation allowed us to know the differences in the content of total polyphenols and antioxidant capacity between tomatoes obtained from different cultivation methods, as well as the effect of mechanical and thermal processing on them. Organic tomatoes both fresh and processed, have a greater total antioxidant capacity than their conventional counterparts, therefore, they can be considered a better alternative for the consumer, due to their important functional value and their favorable impact on health and environment. However, there was no difference in the content of total polyphenols according to method of cultivation in the fresh fruit, though there is a tendency towards a higher content in organic tomatoes. The content of these compounds is the lowest in conventional processed tomatoes. In addition, after mechanical and thermal processing of the fruit, functional properties related to these compounds were maintained, which allows to recommend at home both ways of consumption (fresh or processed), without losing this property. This recommendation does not apply to industrial processes, since they were not evaluated in the present investigation. It is necessary to deepen the study analyzing macro and micronutrients present in organic tomatoes, in order to get more evidence on its nutritional quality.

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