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Changes in bioactive compounds and antioxidant activity during homogenization and thermal processing of tomato puree

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ABSTRACT

The effect of homogenization and thermal processing on a number of bioactive compounds (carotenoids, total phenolics, ascorbic acid and folates) in both raw tomato puree (RTP) and "hot break" tomato puree (HTP) was investigated. RTP and HTP were homogenized in either one or two-steps, followed by pasteurization at 98 °C for 40 s. Additionally, HTP was pasteurized in parallel at 98 °C, 108 °C and 128 °C. In general, homogenization had no effect, but changes were observed after pasteurization (98 °C for 40 s). Carotenoids were relatively resistant to thermal degradation, whereas total phenolic content and ascorbic acid significantly decreased. However, a higher content of folates was determined in the homogenized and pasteurized samples due to their higher extraction from the subcellular compartment. The increase in pasteurization temperatures of the HTP up to 128 °C led to a decrease of ascorbic acid, total phenolic compounds and folates. In conclusion, homogenization and pasteurization at 98 °C for 40 s improves the nutritional value of tomato puree, increasing the extractability of the folates and maintaining the carotenoid content.

Industrial relevance: Unlike other vegetables, the tomato is a staple food that is not frequently homogenized by the processing industry, although homogenization could improve product quality. This is why we explored this technique, using one-step and two-step homogenization. The tomato and vegetable processing industry frequently pasteurizes at a constant flow rate, meaning constant heating time. In this study, we employed three different temperatures, using the same time of exposure, to cover different situations in the food industry. Depending on the product's thickness, an increase in the temperature might be needed to reduce any microbiological hazard in the final product. Homogenization followed by pasteurization at 98 °C for 40 s resulted in a greater improvement of the nutritional value of tomato puree in all situations tested.

1. Introduction

Of all vegetables, the tomato is both qualitatively and quantitatively an important component of the Mediterranean diet, whether consumed raw or as processed tomato products (juice, tomato paste and tomato sauces). Tomatoes are regarded as the most important source of the carotenoid *lycopene*, and a tomato-rich diet is reported to provide protection against some types of cancer and cardiovascular diseases (Sesso, Buring, Norkus, & Gaziano, 2004; Walfisch et al., 2007; Willcox, Catignani, & Lazarus, 2003). However, the healthy effects attributed to tomato consumption might not be limited to lycopene content alone (Jacob, Periago, Böhm, & Berruezo, 2008). Tomatoes also contain a large variety of other micronutrients such as β-carotene, polyphenols, and vitamin C, which are thought to be potent antioxidants. They also contain folate, which could contribute to their beneficial effects (Martínez-Valverde, Periago, Provan, & Chesson, 2002; Periago et al., 2008).

Tomatoes are mainly consumed as a raw staple food due to their desirable nutritional properties, but they are also used to elaborate increasingly popular tomato products. More than 80% of processing tomatoes produced are consumed in the form of processed products such as tomato juice, paste, puree, ketchup, sauce, and salsa. In general, food processing is thought to decrease the nutritional value of staples due to the loss of certain compounds, such as vitamins (Klopotek, Otto, & Böhm, 2005). Nevertheless, it has been previously reported that food processing renders lycopene more available in processed tomato products than in raw tomatoes (Gartner, Stahl, & Sies, 1997). In this regard, investigations have been generally limited to assessing the effect of heat treatment on carotenoids, especially lycopene, in tomatoes (Dewanto, Wu, Adom, & Liu, 2002; Gahler, Otto, & Böhm, 2003; Lin & Chen, 2005). More recently, studies have also described the effect of thermal processing or high-pressure treatment on some antioxidants in tomato juice (Gahler et al., 2003; Hsu, 2008). However, a scant few studies have considered the joint effect of different industrial treatments commonly used in the food industry

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not only on carotenoids or some antioxidants, but also on other bioactive compounds present in tomatoes.

The present study was designed to investigate how the content of several bioactive compounds naturally occurring in tomatoes were affected by industrial processing. Two types of tomato puree commonly used in the food industry, namely raw tomato puree (RTP) and "hot break" tomato puree (HTP), were employed. The bioactive compounds studied included lycopene (including the percentage of all-*trans*-lycopene and *cis*-isomers of lycopene), β-carotene, phenolic compounds, vitamin C, folate, and hydrophilic antioxidant capacity. Industrial processes included homogenization in either one or two steps followed by pasteurization. In the two-step homogenization, the first step reduces the particle size, while the second step is normally used to stabilize the size reached previously. We hypothesized that two-step homogenization could improve the nutritional value of tomato puree by reducing the cellular structure and by achieving a higher extractability of bioactive compounds. Finally, pasteurization at different temperatures was also applied to the HTP to assess the effect of high heat.

2. Materials and methods

2.1. Tomato puree samples and processing conditions

Red intense tomatoes from commercial varieties were selected as raw materials to elaborate the tomato puree. Samples consisted of RTP and HTP (puree produced by the "hot break" method where tomatoes are scalded at 82 °C for 2 min) provided by Juver Alimentación, S.L.U. (Cabezo de Torres, Murcia) and Conserve Italia (Bologna, Italy), respectively. The moisture content of the tomato samples was 94.52% and 94.14% in RTP and HTP, respectively.

To obtain the RTP, 50 kg of commercial varieties of tomatoes, harvested in Murcia (Spain) in June 2006, were crushed and passed through a 0.5 mm sieve to get rid of the skins and seeds. In order to evaluate the effect of both homogenization pressure and thermal treatment, the RTP was subjected to homogenization using a homogenizer (Panda de Soavi, Italy) resulting in a smooth tomato puree. This process was carried out in either one step (100, 150 and 200 bars of pressure; H100, H150, H200) or two steps (150+50, 100+100, 190+20 bars of pressure; H150+50, H100+100, H190+20), followed by a thermal treatment at 98 °C for 40 s in a tubular pasteurizer. The two-step homogenization process consisted of first applying the highest pressure followed by the lowest pressure with a delay < 1 s between both pressures. The effect of homogenization was evaluated alone in "non-pasteurized samples", but homogenization was also evaluated along with the effect of pasteurization in "pasteurized samples".

The HTP was obtained from a blend of industrial tomato varieties, some containing higher levels of lycopene than others, harvested in the same season. In this study, the HTP was exposed to two different treatments: one batch of samples underwent the same processing described for the RTP to determine the effect of homogenization and thermal treatment; while the second batch was exclusively used to evaluate the effect of different pasteurization temperatures (98 °C, 108 °C or 128 °C for 40 s in a tubular pasteurizer) on the bioactive compounds.

The homogenization and pasteurization of both the RTP and HTP were conducted at the pilot plant belonging to Juver Alimentación, S.L.U. (Cabezo de Torres, Murcia). The experimental design is illustrated in Fig. 1. All processed tomato products were stored in screw-cap plastic containers at −80 °C until analysis. Aliquots of 100 mL from RTP and HTP puree were taken for the analysis of each parameter studied.

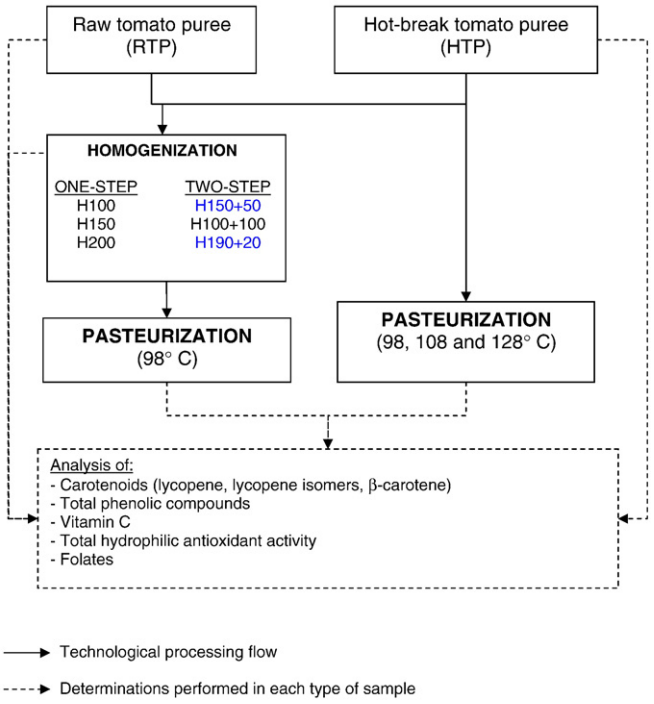

Fig. 1. Flow diagram showing the experimental design of the study.

2.2. Quantitative determinations of bioactive compounds

2.2.1. Carotenoids

Carotenoids were analyzed by HPLC with diode array detection according to Böhm (2001) and Seybold et al. (2004) after three extractions with methanol/tetrahydrofuran (1+1, v/v) containing 0.1% butylated hydroxytoluene. In brief, 400 mg of MgO, 200 μL of *trans*-β-apo-8′-carotenal (internal standard solution), and 35 mL of methanol/tetrahydrofuran were added to 0.6 g of sample and homogenized for 5 min using a blender mixer. The resulting solution was vacuum-filtered through No. 5 Whatman paper. The extraction was repeated twice (until the residue was colourless) and the combined extracts were dried under vacuum at 30 °C in a rotary evaporator. The residue was re-dissolved in methanol:methyl *tert*-butyl ether (1+1, v/v) until the solution reached the defined volume of 10 mL. The solution was centrifuged at 11,000 rpm for 10 min and then used for HPLC analysis, which was done with 1.3 mL min^{-1} methanol (Solvent A) and methyl *tert*-butyl ether (Solvent B) by using a gradient procedure at 17 °C on a C_{30}-column (250×4.6 mm, 5 μm, Trentec, Gerlingen, Germany). The gradient elution started with 90% A and 10% B to reach 55% A at 35 min, 40% at 40 min, then isocratic for 10 min and it finally reached 90% A at 60 min. Lycopene and their *cis* isomers were quantified at 472 nm and β-carotene was quantified at 450 nm. Since standards of lycopene *cis* isomers were not available, they were tentatively identified based on retention times and absorption spectrum characteristics described in the literature (Seybold et al., 2004; Fröhlich, Conrad, Schmid, Breithaupt, & Böhm, 2007). Carotenoid content was expressed as mg/kg of tomato puree.

2.2.2. Total phenolic compounds

Total polyphenol content was quantified using a colorimetric assay and Folin-Ciocalteau's phenol reagent (Sigma, St. Louis, USA) according to the method described by Singleton and Rossi (1965). Before the colorimetric analysis, the samples were subjected to a procedure of extraction/hydrolysis. For that, 1 mL of 1 M HCl was added to 2 g of the sample, vortexed for 1 min and incubated at 37 °C for 30 min. Later, 1 mL of 2 M NaOH in a 75% methanol solution was added, and the resulting mixture was vortexed for 2 min and incubated at 37 °C for 30 min. Then, 1 mL of 0.75 M of metaphosphoric acid was added after vortexing for 2 min and the sample was centrifuged at 5000 rpm for 10 min. The supernatant was removed, transferred into a 10 mL volumetric flask and the pellet was re-suspended in 1 mL of acetone:water (1:1, v/v), vortexed for 1 min and centrifuged at 5000 rpm for 10 min. Finally, both