Food Chemistry 124 (2011) 1603–1611

Contents lists available at ScienceDirect

Food Chemistry

journal homepage: www.elsevier.com/locate/foodchem

Changes in the contents of carotenoids, phenolic compounds and vitamin C during technical processing and lyophilisation of red and yellow tomatoes

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ARTICLE INFO

Article history:
Received 25 March 2010
Received in revised form 30 July 2010
Accepted 11 August 2010

Keywords:
Red tomato
Yellow tomato
Processing
Lyophilisation
Antioxidant
Carotenoids
Phenolic compounds
Vitamin C

ABSTRACT

We present the results of the first study on the impact of thermal processing and lyophilisation on three major micronutrient families: carotenoids, total polyphenols and vitamin C in two different tomato cultivars: a red tomato (RT) and a yellow one (YT). Micronutrients were analysed in fresh tomatoes, tomato purée and lyophilised tomatoes. YT contained no lycopene, lower β-carotene, similar vitamin C and higher total polyphenol contents than RT. Processing did not affect the carotenoid content in RT, but significantly lowered β-carotene in YT and also the contents of total polyphenol and vitamin C in both cultivars. Lyophilisation lowered the carotenoid content in RT but not in YT; in contrast, the total polyphenol content was preserved in RT but lowered in YT, and the vitamin C content was not affected in both cultivars. These results provide new data on the effect of thermal processing and lyophilisation on the content of the three main families of micronutrients in red and yellow tomatoes.

1. Introduction

Tomato is the second most consumed vegetable in the world, after potato, (<http://faostat.fao.org>), and approximately 30% is consumed as transformed products. Among them, tomato powder is a common product widely used by food processors. Consumption of processed tomato products is rising in western countries. Between 1996 and 2001, the quantity of processed tomatoes increased from 7.88 to 8.45 million tons in the EU (<www.wptc.to>). Tomato, as a fresh or transformed product, possesses a high nutritional value, due to its content of different types of micronutrients: vitamins (C and E), folates, carotenoids and phenolic compounds (Beecher, 1998; Periago & Garcia-Alonso, 2009). Tomato is the main source of lycopene in the western diet. This carotenoid confers the characteristic red colour. Epidemiological studies have suggested that people with a high lycopene intake from tomato products have a lower risk of prostate cancer (Giovannucci, 2005), although controversy still remains among the scientific community.

Whereas numerous studies on the micronutrient content of fresh tomato have been conducted, very little is known about the effects of processing on its nutritional quality, and controversial results can be found in the literature. Most of these studies focused on the loss of one type of micronutrient, e.g., one carotenoid, mainly lycopene (Graziani et al., 2003; Sharma & LeMaguer, 1996) or two types of micronutrients, such as phenolic compounds and vitamin C (Gahler, Otto, & Böhm, 2003) or flavonoids and carotenoids (Re, Bramley, & Rice-Evans, 2002). However, only a few studies describe the impact of technological processes on various antioxidants in tomatoes, thus taking account of the different parameters implied in the nutritional value of tomato, such as lycopene, vitamin C and phenolic compounds (Capanoglu, Beekwilder, Boyacioglu, Hall, & De Vos, 2008; Dewanto, Wu, Adom, & Liu, 2002), or lycopene, vitamin C, phenolic compounds and folates (Perez-Conesa et al., 2009), or lycopene, vitamin C and vitamin E (Abushita, Daood, & Biacs, 2000).

Lyophilisation is often used at the laboratory level to dehydrate fresh biological material for storage because no enzymatic reactions can occur in the dry state. Freeze-dried botanical samples can also be found as commercial products in the public area. It is commonly assumed that the lyophilisation process itself does not

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doi:10.1016/j.foodchem.2010.08.024

affect the composition of the plant material. However, few analytical data are available to confirm this assumption (Abascal, Ganora, & Yarnell, 2005).

In this paper, we describe the effect of a classical thermal process to produce tomato purée and a freeze-drying treatment on the three main families of bioactive components of tomato: carotenoids, phenolic compounds and vitamin C. Two varieties of tomatoes were chosen for their different carotenoid content: a red cultivar and a yellow one. Their content of targeted micronutrients in the fresh state was compared to those after processing and lyophilisation.

2. Materials and methods

2.1. Tomato growth conditions and harvesting

Two genotypes of tomato plants, one producing red fruits (*Solanum lycopersicum* L. cv. Cheers, De Ruiter) and the other producing yellow fruits (*Solanum lycopersicum* L. cv. 6205, Séminis) were grown during spring 2006, on N–S oriented coco slabs in the same glasshouse at Bellegarde in Southern France (43.75°N, 4.5°E). Nutrient supply as well as chemical control of pests and diseases followed commercial practices. Water was supplied to the plants according to the potential evapotranspiration in order to maintain 20–30% drainage. Flowers were open-pollinated by bumble bees and all side shoots were removed as they appeared. Every fortnight, old leaves were removed up to the youngest turning truss. Mature red and yellow tomatoes were harvested at three different times between June 8th and July 20th 2006, in order to be representative of fruits grown during summertime. The maturity stage was harmonised according to the external colour of the fruit and its firmness (measured with a Durofel; COPA-Technologie SA, St Etienne du Grès, France). The maturity stage corresponded to the red-ripe stage for the red tomato and to a golden-yellow colour for the yellow tomato.

2.2. Sampling and colour measurement

At each harvest, samples of both red and yellow tomatoes were taken from three batches of 13 tomatoes, representative subsets of the harvested tomatoes. The external colour was measured near the pistil scar by a Minolta chromameter (CR 300; Minolta SA, Carrières-Sur-Seine, France) using the CIELAB ($L^*a^*b^*$) colour space (Hunter colour coordinates, where L^* represents lightness, a^* ranges from green to red, b^* ranges from blue to yellow). The values a^* and b^* were used to calculate the hue angle ($H = \arctan(b^*/a^*)$) and metric chroma value ($C = (a^{*2} + b^{*2})^{1/2}$).

Tomato fruit were cut into quarters; two opposite quarters of each tomato fruit were chopped to reduce their size to less than 1 square cubic centimetre, immediately frozen in a freezing tunnel at −30 °C and then stored at −80 °C until they were ground to a homogeneous powder in liquid nitrogen. Aliquots of powder were prepared and stored at −80 °C for a maximum of 3 months until they were analysed. Such samples are regarded as fresh tomato in this work.

2.3. Lyophilisation

Aliquots of tomato powder (prepared as described in Section 2.2) were submitted to a one-week lyophilisation (freezing at −20 °C, followed by two successive drying steps at 0.5 mbar and 0.1 mbar, respectively, at 10 °C). The samples were stored at −20 °C for a maximum of 3 months until they were analysed.

2.4. Tomato processing

Tomato purée was produced from three batches of red or yellow tomatoes that had been harvested at three different times. The tomatoes were processed in a pilot plant at the French Technical Centre for Food Industry (CTCPA, Avignon, France). For each batch, the tomatoes were washed for 5 min in three volumes of water under slight agitation, ground with a hammer mill (Fryma) before being heated for 10 min at 92 °C in a tubular heat exchanger. The mixture was then passed through a sieve (Robocoupe) equipped with a 1-mm grid, to remove seeds and residual skins. The mixture was concentrated under a pressure of −0.96 bar at 65 °C, until it reached 14 Brix. The purée was filled into 425-ml cans, pasteurised by immersion at 100 °C for 10 min, and then stored at 4 °C. The three resulting tomato purées were mixed, canned and subjected to a final thermal treatment at 100 °C for 50 min (Fig. 1). The dry matter contents of the red and yellow tomato purées were analysed by vacuum-drying the samples for at least 6 h at 60 °C to constant weight.

2.5. Chemicals

The standard chemicals (lycopene, β-carotene) were purchased from Sigma (St Quentin-Fallavier, France). Acetone (p.a.), acetonitrile (HPLC grade), ethanol (p.a.), *n*-hexane (p.a.), methanol (HPLC grade), petroleum ether 35–60° and L-ascorbic acid were purchased from Carlo Erba (Val de Reuil, France). Folin–Ciocalteu reagent, gallic acid and 1,2-*o*-phenylenediamine were purchased from Merck (Limonest, France). Ascorbate oxidase spatulas were purchased from Roche Diagnostics GmbH (Mannheim, Germany).

2.6. Analysis of carotenoids

2.6.1. Extraction methods

The efficiency of two different solvent mixtures on the extraction of carotenoids from red processed tomato (1–10 g of red tomato purée) was compared: a mixture of hexane/acetone/ethanol (50/25/25, v/v/v, HAE) inspired by Sadler and Davis (1990), and acetone/petroleum ether (Buret, 1991). The first procedure involved placing tomato material in a beaker with 100 ml HAE in the dark. The mixture was thoroughly agitated with a magnetic stirrer for 20 min. The extract was filtered and then transferred into a separating funnel. The organic phase was washed three times with 20 ml distilled water to remove acetone and ethanol. The aqueous phase was discarded, remaining water in the organic phase was removed with anhydrous sodium sulphate, and the volume was made up to 50 ml with hexane. The second procedure involved extracting with acetone as follows: tomato material was mixed with 50 ml acetone for 20 min in the dark, and the mixture was filtered through carded cotton. Carotenoids from the remaining material were subsequently extracted in the same way twice by mixing with 30 ml acetone for 5 min and combining the filtrates in a separating funnel. Petroleum ether (75 ml) was added, and the organic phase was washed three times with 50 ml water. Remaining water was removed with anhydrous sodium sulphate, and the volume was made up to 100 ml with petroleum ether.

Carotenoids from frozen and lyophilised tomato were obtained by solid/liquid extraction from an appropriate amount of material (i.e., 2–10 g frozen powder, or 0.1 g lyophilisate) using the acetone method described above.

2.6.2. Quantitative analysis

The concentrations of lycopene and β-carotene were determined spectrophotometrically (Perkin Elmer – Lambda 25) using the following equations (Lime, Griffiths, O'Connor, Heinzelman, & McCall, 1957):

$$C_{\beta-\text{carotene}} = 4.624 \times A_{450} - 3.091 \times A_{503} \quad (1)$$

$$C_{\text{lycopene}} = 3.956 \times A_{450} - 0.806 \times A_{503} \quad (2)$$