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Industrial processing versus home processing of tomato sauce: Effects on phenolics, flavonoids and *in vitro* bioaccessibility of antioxidants

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ABSTRACT

The effect of industrial and home processing, *in vitro* gastrointestinal digestion, individual phenolic content, and antioxidant capacity of tomato into tomato sauce were investigated. Industrial processing of tomato fruit into sauce had an overall positive effect on the total antioxidant capacity (∼1.2-fold higher) compared to tomato fruit whereas home processing of tomato fruit into sauce led to a decrease in these values. Untargeted LC–QTOF-MS analysis revealed 31 compounds in tomato that changed upon processing, of which 18 could be putatively identified. Naringenin chalcone is only detectable in the fruit, while naringenin is strongly increased in the sauces. Rutin content increased by 36% in the industrial processed sauce whereas decreased by 26% in the home processed sauce when compared to fruit. According to the results of an *in vitro* gastrointestinal digestion model, industrial processing may lead to enhanced bioaccessibility of antioxidants.

1. Introduction

In the Western diet, tomatoes are a major source of nourishment for the world's population due to their large consumption and versatility. They can be used for direct consumption (fresh/raw) or as an ingredient in many food recipes (Knockaert et al., 2012). Tomato is an important fruit in Turkey, with a production level of 11 million tonnes in 2013 (FAOSTAT, 2013). Most of the world's tomato crops are processed each year to produce a variety of tomato products including canned tomatoes, juices, sauces, purees, and pastes (Vallverdú-Queralt, Martínez-Huélamo, Casals-Ribes, & Lamuela-Raventós, 2014; Tulipani et al., 2012). Tomatoes are rich in lycopene, a carotenoid which is important because of its health related properties (Knockaert et al., 2012). Epidemiological evidence suggests an association of phytochemicals such as carotenoids and phenolics to a reduced risk of various chronic diseases such as cardiovascular disease and certain types of cancer and especially, prostate cancer (Afrin et al., 2016; Chiva-Blanch & Visioli, 2012; Forbes-Hernandez et al., 2016; Forbes-Hernández et al., 2014; Pistollato, Giampieri, & Battino, 2015). These health protective effects have been widely attributed to the presence of key antioxidants such as lipid-soluble lycopene and β-carotene, as well as water-soluble vitamin C, and compounds of intermediate hydrophobicity such as quercetin glycosides, naringenin chalcone, and chlorogenic acid (Capanoglu, Beekwilder, Boyacioglu, Hall, & De Vos, 2008). Antioxidants present in food undergo chemical changes during technological processing. Domestic and commercial food processing has typically drastic effects on the structural integrity of fruits and vegetables (Kalt, 2005). Home cooking of tomatoes is very prevalent in Turkey. Many fruits and vegetables have already been investigated for changes in their antioxidants as a result of processing including tomato (Capanoglu et al., 2008), sour cherry (Toydemir et al., 2013), and black mulberry (Tomas et al., 2015). To our knowledge there is no report in which the effect of industrial processing and home processing have been compared.

Bioaccessibility, which is defined as the fraction of the nutrient that can be released from the food matrix (Colle, Lemmens, Van Buggenhout, Van Loey, & Hendrickx, 2010), was measured using an *in vitro* method. Several studies indicated that cooking may also enhance digestibility and bioavailability of food nutrients (Van Boekel et al., 2010). Martínez-Huélamo et al. (2015) showed that mechanical and thermal treatments during tomato sauce processing may increase the bioaccessibility, extractability and bioavailability of phenolics in tomato.

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The effects of industrial processing on the antioxidants of tomatoes have been extensively studied. However, little is known about the impact of different processing methods on tomato and tomato sauce. Therefore, in this study the aim was to compare the effect of industrial-scale preparation and home cooking on tomato antioxidants during sauce production. Using an untargeted LC–MS analysis, a number of phenolic compounds were monitored and identified in tomato and different processed tomato sauces. Moreover, an *in vitro* simulated gastrointestinal digestion model was used to determine the effect of these different processing techniques on the bioaccessibility of tomato antioxidants.

2. Materials and methods

2.1. Tomato sauce material

A commercial tomato variety (*Lycopersicum esculentum* var. Advance harvested from a greenhouse in Manisa, Turkey in 2015), suitable for tomato sauce preparation, was used for the study. The tomato sauce was prepared by two different processing methods (industrial and home processing) using the same fresh tomatoes (4.5 °Brix, 4.3 pH) according to the flow sheet represented in Fig. 1. Processing of each sauce has been repeated three times as three independent experimental units (EU), and three technical replicates were analyzed from each EU.

Industrial processed sauce: Tomatoes were processed into sauce in a factory (Döhler, Balıkesir, Turkey) in 2015. The processing steps included washing, cold breaking (73 °C, 10 min), evaporating (11 °Brix, 73 °C), and pasteurization (110 °C, 90 s) to generate the standard commercial product. The final sauce had 11 °Brix with a pH of 4.4. The final sauce contains the seed and the skin fractions as they are not removed during the process.

Home processed sauce: Home processing was performed following a typical Turkish recipe. Tomatoes were washed, chopped (~10 cm^3) and crushed with a home type blender. The mixture was cooked for 60 min at 100 °C. The final sauce had a °Brix of 14. The final sauce contains the seed and the skin fractions as they are not removed during the process. Both for home processing and industrial processing, three independent processing events were sampled. Therefore, the analysis included three independent fruit samples, three independent home-processing sauce samples and three independent industrial processing sauce samples (Fig. 1). For spectrophotometric methods and HPLC analysis each independent sample was analyzed in triplicate (technical replicates) (n = 9). Only for the LC–MS analysis each EU was analyzed only once (n = 3). All samples were ground to a fine powder in liquid nitrogen using a pre-cooled grinder (IKA A11, Germany), and stored at −80 °C before analysis.

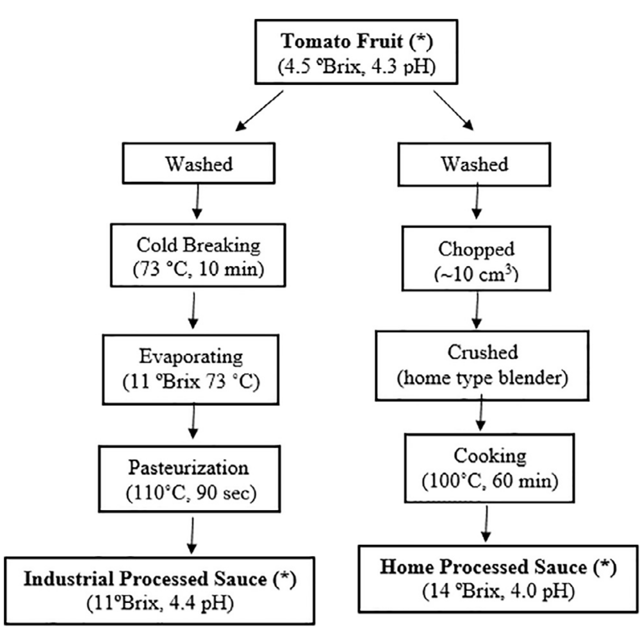

Fig. 1. Flowchart of tomato sauce processing (∗, samples taken for analysis).

2.2. Moisture content analysis

The moisture contents of samples were determined according to the guidelines of the official Turkish Standard 1129-ISO 1026 method at 70 °C for 6 h using a vacuum oven (Gallenkamp, London, UK). All samples were analyzed in triplicate and mean values were reported.

2.3. Extraction method

Tomato samples (2.0 g) were homogenized with 5 mL of 75% aqueous methanol containing 0.1% formic acid following a procedure described previously by Capanoglu et al. (2008). The samples were then sonicated for 15 min and centrifuged (2700 rpm at 4 °C) for 10 min and the supernatants were collected. This extraction procedure was repeated twice, and three supernatants were pooled. These extracts were stored at −20 °C until analysis.

Individual black mulberry phenolics were identified and quantified by using targeted HPLC and untargeted LC–QTOF-MS measurements. For these, the samples were prepared by the extraction of 400 mg freeze-dried material with 3.0 mL of 75% aqueous methanol with 0.1% formic acid. After the steps of sonication for 15 min and centrifugation at 2500 rpm for 10 min; the extracts were filtered through 0.45 µm filters (Minisart SRP4, Biotech GmbH, Germany).

2.4. Spectrophotometric assays

Total antioxidant capacity (TAC) assays were performed using a spectrophotometer. TAC was estimated using four different assays, and in all assays, the results were expressed in mg of Trolox equivalent (TE) per 100 g DW. The ABTS (2,2-azinobis 3-ethylbenzothia zoline-6-sulphonic acid), FRAP (ferric reducing antioxidant power), CUPRAC (copper reducing antioxidant capacity), and DPPH (1,1-diphenyl-2-picrylhydrazyl) assays were performed according to Miller and Rice-Evans (1997), Benzie and Strain (1996), Apak, Güçlü, Özyürek, and Karademir (2004), and Kumaran and Karunakaran (2006), respectively.

2.5. Untargeted LC–MS based identification

An LC-PDA-FTMS system was used to investigate the untargeted analysis of tomato samples. Chromatographic and mass spectrometric conditions were as described by Moco et al. (2006). Briefly, a Luna C18(2) pre-column (2.0 × 4 mm) and an analytical column (2.0 × 150 mm, 100 nm, particle size 3 µm) from Phenomenex (Torrance, CA, USA) were used for chromatographic separation. UV absorbance was performed with a Waters 2996 PDA (range from 240 to 600 nm) and metabolites were detected using a LTQ-Orbitrap XL hybrid MS system (Waters) operating in negative electrospray ionization mode heated at 300 °C with a source voltage of 4.5 kV for full-scan LC–MS in the *m*/*z* range 100–1500.

Compounds naringenin, naringenin chalcone, quercetin, dihydrokaempferol, α-tomatine, coumaroyl quinic acid and isoquercetin were obtained from Extrasynthese (Genay, France), and analyzed as reference compounds.