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Impact of long-term storage at ambient temperatures on the total quality and stability of high-pressure processed tomato juice

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ABSTRACT

High-pressure processing (HPP) can produce tomato juice of high quality and safety with a short shelf life under refrigeration temperatures. Long-term higher temperature storage studies are rare and temperature tolerant products are challenging to develop. The effect of high-pressure processing (HPP) on the total quality (colour, microbial counts, phytochemical levels, antioxidant and enzymatic activities) and stability (retention over time) of tomato juice during long-term storage was investigated. Thermal processing (TP) was used as a control treatment, and overall, two different ambient conditions (20 °C and 28 °C) were tested. Immediately after processing, HPP products proved superior to TP ones (enhanced redness, total carotenoids and lycopene, stable total phenols and inactivation of pectin methyl esterase). During initial storage (30 d) most quality attributes of HPP juice remained stable. Prolonged storage, however, led to losses of most quality attributes, although HPP (20 °C) showed lower quality degradation rate constants comparison to TP and HPP (28 °C).
Industrial Relevance: There is a demand for ambient stable tomato products, especially in some parts of the world, and current industrial practices (canning, pasteurisation) either compromise in product quality or require refrigeration conditions. High-pressure processing has been investigated as milder technology, with a potential to deliver superior quality. The drawback is that is also requires chill storage. The results of this study show how quality parameters behave in a high-pressured tomato product and pave the way for further development that could optimise this technology. This could be of economic importance for the tomato juice industry to develop new products stable in ambient temperatures and perhaps beneficial for cutting down the refrigeration costs under specific conditions.

1. Introduction

Tomato (*Solanum lycopersicum* L.) is the second most widely grown vegetable crop in many countries across the globe and is consumed in large quantities partly due to its nutritional, functional and health properties (Clinton, 1998; Takeoka, Dao, Flessa, Gillespie, Jewell, & Huebner, 2001). Awareness of healthy eating has grown amongst modern consumers who are seeking nutrient dense and convenient foods such as tomato juice. Processing is essential to ensure the total quality of tomato juice and to maintenance or stabilise these qualities until consumption. Conventional processing techniques, such as heating, may induce undesirable changes in organoleptic properties and reduce the bioavailability of micronutrients (Patras, Brunton, Pieve, Butler, & Downey, 2009). Nonthermal processing technologies are emerging as alternatives that claim no compromise in safety while ensuring higher retention of important nutrients. There is an opportunity for the food industry, in particular tomato processors, to adapt and develop new safe products that guarantee unprecedented quality and 'freshness' characteristics.

As a non-thermal processing technique, high-pressure processing (HPP) applies a pressure between 200 and 600 MPa to inactivate vegetative microorganisms, some enzymes and to preserve quality attributes. Many authors have assessed the effect of HPP on quality and micronutrients of tomato juice and purée in comparison to thermal processing (TP), and it has proved useful for preserving the quality of tomato juice and purée after treatment (Dede, Alpas, & Bayindirli, 2007; Hsu, 2008; Krebbers, Matser, Hoogerwerf, Morzelaar, Momassen, & Van den berg, 2003; Patras et al., 2009; Porretta, Birzi, Ghizzoni, & Vicini, 1995; Sanchez-Moreno, Plaza, Ancos, & Cano, 2006). Alongside nutrient retention inactivation of two enzymes, pectin methyl esterase (PME) and polygalacturonase (PG) is very important to maintain the desired viscosity of tomato juice and purée. Several researchers have investigated the effect of HPP on PME and PG activities at various temperatures (Boulekou, Mallids, Taoukis, & Stoforos, 2011; Crelier, Robert, Claude, & Juillerat, 2001; Fachin, Van Loey, Nguyen, Verlent, Indrawati, & Hendrickx, 2003; Hsu, 2008; Krebbers et al., 2003; Verlent, Van Loey, Smout, Duvetter, & Hendrickx, 2004), and they

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found total inactivation of PG and contradictory behaviour of PME at some pressure/temperature conditions (500–800 MPa/20–90 °C). Colour retention is also very important quality attribute of tomato juice. It is established that pH has an important effect on pigments and responsible for the colour of fruits and vegetables during processing (Andres-Bello, Barreto-Palacios, Garcıa-Segovia, Mir-Bel, & Martinez-Monzo, 2013), but the impact of reducing pH on the maintenance of tomato juice quality has not been widely investigated.

Maintaining quality and nutritional properties of tomato juice throughout long-term storage at higher temperatures is very challenging but would be extremely useful especially for tropical countries of high ambient temperatures, where low temperature storage facilities are not adequately available, to preserve large quantities of tomatoes produced during the glut season. Surprisingly few researchers have reported the effect of HPP on quality attributes during long-term storage under such conditions and the results are contradictory. Gupta, Balasubramaniam, Schwartzand Francis (2010) claimed that HPP (500–700 MPa) can result in a microbiologically safe tomato juice product for 52 weeks at 25 and 37 °C, whereas Dede et al., 2007) showed more moderate results after 4 weeks at 25 °C using much lower pressures (150–250 MPa). As well as microbiological stability, the fate of minor constituents and other crucial quality parameters of tomato juice during storage at ambient temperature have not been well studied. Only one study reported on the complete antioxidant activity, ascorbic acid content and colour degradation after HPP treatment, although only for limited amount of time (Dede et al, 2007). Their results showed better retention of ascorbic acid, antioxidant activity and colour than the conventional, thermally processed samples. The long-term, high temperature storage study of Gupta et al. (2010) considered some quality parameters (colour, lycopene content) and found better retention throughout storage compared to heat treatment, although the effect on other important nutritional parameters such as ascorbic acid, total phenol content and related antioxidant activities and enzyme activities that are essential in assessing the stability of long storage products was not addressed.

Most importantly, most of the HPP studies cited, including the two above, have been conducted using laboratory scale HPP equipment where the capacity is below 5 L. Results obtained using this type of experimental equipment may not necessarily reflect results acquired using industrial processors and usually significant charges are required for scaling up.

Therefore, studying the effect of HPP on the quality of tomato juice during long-term storage is an important consideration in evaluating novel processing methods in comparison to existing practices. The aim of this study was to evaluate the effects of industrial scale HPP on microbiological quality, appearance and nutrient retention of tomato juice in comparison to TP during long-term storage at two different ambient conditions (20 °C and 28 °C). The effect of juice pH on the quality parameters was also investigated.

2. Materials and methods

2.1. Materials

All chemicals and standards except for nutrient agar and maximum recovery diluent (Oxoid, Basingstoke, UK) were purchased from Sigma Aldrich (Dorset, UK) and were of analytical grade. Fully ripe tomatoes (cv *Pitenza*, cultivated in Spain) were purchased at 3 different occasions from local stores in Northern Ireland (UK) between April to May 2013. In total, 45 kg of tomatoes were purchased and graded before processing (mean weight, 85 ± 5 g and mean circumference, 15 ± 1 cm), odd shape and size tomatoes were excluded. Cheese cloth (100 × 100 cm) was purchased in the local market and standard packaging materials (polyethylene/polyamide film) were obtained from Scobie & Junor (Mallusk, UK).

2.2. Sample preparation

Tomatoes were washed, cut into pieces and blended using a household blender. The seeds and skin of the tomato were removed by passing the resulting juice through a cheese cloth. The juice was divided into three aliquots and the pH of one aliquot of tomato juice was altered to pH 3.93 by adding citric acid. The pH of the other two aliquots was left unaltered, at the original pH of 4.3. Samples of juice (50 ml) were transferred into polyethylene/polyamide pouches (15 × 10 cm), heat sealed and kept under refrigeration (4 °C) until processing.

2.3. High-pressure (HP) and thermal processing (TP) and storage study design

Tomato juices of altered and unaltered pH were blanched using hot break method at 90 °C for 2 min (Hayes *et al.*, 1998) using a water bath (Grant, GD 100, UK). The temperature of the juice during blanching was monitored using a digital thermometer (HI 98804, Hanna Instruments, UK) fitted with a k-type thermocouple, and samples were cooled in iced water immediately after blanching. The samples for HPP were treated using an Avure Quintus 35 L (Avure Technologies, Middletown, OH, USA) with a heat-controlled vessel and a capacity of 35 L (internal diameter: 18 cm, length: 1.2 m) and pressurised (600 MPa/1 min) at ambient temperature (approximately 16 °C). The temperature increase due to adiabatic heating was approximately 3 °C per 100 MPa. Time taken to reach the target pressure was approximately 2 min and decompression took approximately10 sec. For comparison with conventional heat processing, heat sealed pouches of tomato juice were subjected to thermal processing using a water bath at 95 °C for 20 min (Hayes, Smith, & Morris, 1998), as described above. The entire experiment was conducted on three separate batches, on three consecutive days to produce three replicate samples.

HPP and TP samples were stored for up to 12 months at two different ambient temperature (20 °C and 28 °C) conditions and analysed after 0, ½, ¾, 1, 2, 3, 6, 9 and 12 months storage for microbial counts, colour, phytochemicals, antioxidant activity and enzyme activity. Phytochemicals, antioxidant activity and enzyme activity analyses were carried out on freeze-dried samples, taken at each sampling time but processed all at the same time (i.e., after 12 months). Freeze drying was achieved using a freeze dryer (Christ-Alpha 1–4 LD, Germany).

2.4. Microbiological analysis

Total viable count (TVC) was determined using Nutrient agar. Tomato juice (1 ml) was aseptically transferred to 9 ml maximum recovery diluent and serial dilutions prepared. Aliquots (100 μl) of appropriate dilutions were spread plated on duplicate nutrient agar plates. After incubation at 30 °C for 24 h, colonies were counted and results were expressed as CFU/ml of tomato juice.

2.5. Colour measurements

Colour was measured using a Konica Minolta portable colorimeter (CR-410, Japan). A standard white tile ($X = 87.01$, $Y = 0.3185$, $Z = 0.3365$) was used to calibrate the instrument and L^*, a^* and b^* values were directly taken from the colorimeter. The Hue value (a/b) and the overall colour change ($\Delta E = \sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$) were calculated based on measured L^*, a^* and b^* values.

2.6. Quantification of total carotenoids and lycopene content

Total carotenoids were determined according to Koca, Burdurlu and Karadeniz (2007) with some modifications. Freeze-dried tomato samples were extracted with hexane:acetone (7:3) (0.5 g/25 ml), and total carotenoids were quantified with colorimetric detection at 450 nm using UV–vis spectrophotometer (JENWAY 6305, UK) and β-carotene