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Impact of different large scale pasteurisation technologies and refrigerated storage on the headspace fingerprint of tomato juice

Kemal Aganovic [a,*], Tara Grauwet [b], Biniam T. Kebede [b], Stefan Toepfl [a], Volker Heinz [a], Marc Hendrickx [b], Ann Van Loey [b,**]

[a] German Institute of Food Technologies (DIL) e.V., Prof.-von-Klitzing-Str. 7, D-49610 Quakenbrück, Germany
[b] Laboratory of Food Technology, Leuven Food Science and Nutrition Research Center (LFoRCe), Department of Microbial and Molecular Systems (M^2S), Katholieke Universiteit Leuven, Kasteelpark Arenberg 22 box 2457, B-3001 Heverlee, Belgium

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ABSTRACT

This work reports an evaluation and comparison of traditional and novel large scale pasteurisation technologies (pulsed electric fields (PEF) and high pressure processing (HPP)) and consecutive refrigerated storage on the headspace fingerprint of tomato juice. The comparison between technologies was performed based on microbial equivalence. A pilot scale PEF processing system and an industrial scale HPP unit were used in order to imitate industrial application. A fingerprinting approach ('processomics') as a hypothesis-free approach has been used for sample comparison, as volatiles are often involved in process- and storage-induced chemical reactions as intermediate or end products. It has been observed, that all three pasteurisation technologies caused loss of several volatiles compared to non-processed sample. Moreover, all three technologies caused increase of *Z*-citral and 6-methyl-5-hepten-2-one. The majority of the quality-related chemical reactions observed after processing and during shelf-life were oxidative reaction of fatty acids, carotenoid degradation and degradation of amino acids.

Industrial relevance: Tomato processing often includes thermal treatments, which can adversely influence sensory and quality attributes of the final product. Novel technologies such as pulsed electric fields (PEF) and high pressure processing (HPP) have been investigated and developed as gentle pasteurisation technologies, with a potential to deliver the product with superior quality compared to their thermal counterparts. The results of this study could be of great importance for implementation of novel technologies and could lead to a new product development and process optimisation. In case of PEF technology, the process efficiency might be an important factor, considering that lower energy levels are needed for pasteurisation and higher capacities can be produced (operating in a continuous process) with extremely short holding times at elevated temperature.

1. Introduction

Tomato (*Lycopersicum esculentum* L.) is one of the most important vegetables worldwide. It is used by consumers as a fresh product and in food industry as a raw material for production of several processed products. Frequently, processing of tomato includes thermal treatments (e.g. blanching, pasteurisation or sterilisation), ensuring microbial and/or enzymatic stability of the product. These thermal treatments can adversely influence sensory and nutritional qualities of the product, by enhancing different chemical reactions such as oxidation of carotenoids, oxidation of fatty acids and Maillard reactions (McDonald, McCollum, & Baldwin, 1996). Therefore, alternative technologies (often described as "non-thermal", "emerging" or "novel") for traditional thermal treatment, such as pulsed electric fields (PEF) and high pressure processing (HPP) were developed and investigated. As a result of the research and development performed in this field, in literature, valuable reports can be found on (i) inactivation kinetics of various microflora and enzymes using novel technologies; (ii) their impact on different food matrices and food quality characteristics; and (iii) technical improvement and scalability of the processing equipment (Heinz & Buckow, 2009; Heinz, Toepfl & Knorr, 2003; Hendrickx, Ludikhuyze, Van den Broeck & Weemaes, 1998; Oey, Lille, Van Loey & Hendrickx, 2008; Panozzo et al., 2013; Saldana, Puertolas, Condon, Alvarez & Raso, 2010; Toepfl, 2011; Toepfl, Heinz & Knorr, 2007; Van Loey, Verachtert & Hendrickx, 2002).

In particular for tomato juice, some insight in the impact of novel technologies (mostly HPP) is described in literature already. Some authors described the high pressure processed food to be superior in quality to its thermally treated counterparts or to be comparable to its fresh equivalents (Boulekou, Mallidis, Taoukis & Stoforos, 2011; Butz et al., 2003; Hsu, 2008a; Viljanen, Lille, Heinio & Buchert, 2011). Boulekou, Mallidis, Taoukis and Stoforos (2011) studied quality attributes of concentrated tomato juice, produced from tomatoes previously treated by high pressure. It was concluded that HPP could be used as

* Corresponding author. Tel.: +49 5431 183 447; fax: +49 5431 183 114.
** Corresponding author. Tel.: +32 16 32 15 72; fax: +32 16 32 19 60.
E-mail addresses: k.aganovic@dil-ev.de (K. Aganovic), ann.vanloey@biw.kuleuven.be (A. Van Loey).

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alternative technology for thermal processing of tomato juice with improved quality attributes such as viscosity, colour and consistency. HPP effects on inactivation of vegetative cells and quality attributes (colour, carotenoids, viscosity and vitamin C) in tomato juice were evaluated and compared to thermally processed juice during refrigerated storage for 28 days (Hsu, 2008a; Hsu, Tan & Chi, 2008b). In this study, HPP has been reported as a good alternative for thermal processing of microbial stable tomato juice. Moreover, pressure treated juice resulted in a juice with improved colour, relatively higher vitamin C content and increase in extractable amount of carotenoids. Comparable results were observed by Dede, Alpas and Bayındırlı (2007), who studied the effects of HPP and thermal pasteurisation on microbial load and quality aspects (antioxidant scavenging capacity, ascorbic acid, pH and colour) of tomato and carrot juice. High pressure treatments of at least 250 MPa, in combination with 35 °C and 15 min, were effective in producing microbial-stable products. The HPP produced juice was reported as a product with superior quality, compared to the thermally processed one in terms of microbial stability, ascorbic acid retention and antioxidant activity.

On the other hand, several studies reported HPP as rather unfavourable preservation technique for tomato juice. Viljanen, Lille, Heinio and Buchert (2011) reported loss of fresh odour and increase of cooked flavour of tomato purée after high pressure treatment of 800 MPa at 20 and 60 °C, compared to fresh unprocessed tomato purée. Increased level of free fatty acids oxidation and a rancid flavour after HPP was reported by Porretta, Birzi, Ghizzoni and Vicini (1995). In their study they raised a question of HPP applicability for tomato juice preservation.

Contrary to HPP, the effect of PEF processing on tomato juice was investigated to a lesser extent. The effect of moderate intensity PEF treatment on whole tomatoes (electric field strength of 1 kV/cm), following juice production and PEF treatment of the juice were studied (electric field strength of 35 kV/cm) (Vallverdu-Queralt et al., 2013). The authors reported that PEF induced stress responses in tomatoes enhancing the metabolic activity, resulting in increased concentration of lutein, α- and β-carotene and *trans*-lycopene. Moreover, a loss of individual health related compounds in fresh, thermal and PEF treated tomato juices during storage (except *cis*-lycopene isomers) was reported. Similar studies were conducted by Odrizola-Serrano and authors (Odriozola-Serrano, Soliva-Fortuny, Gimeno-Ano & Martin-Belloso, 2008; Odriozola-Serrano, Soliva-Fortuny, Hernandez-Jover & Martin-Belloso, 2009) on tomato juice and consistent results were observed, confirming PEF induced release of some compounds, appearing in increased concentration of detectable total and individual carotenoids (lycopene, β-carotene and phytofluene). Effects of commercial scale PEF equipment on safety and quality of tomato juice were studied and compared to its thermal counterpart (Min, Jin, & Zhang, 2003a). The PEF treated tomato juice was characterised by a better retention of flavour, colour and overall acceptability, but also significantly smaller particles in PEF processed tomato juice compared to thermal and non-processed juice. At the same time, no significant changes were observed for lycopene, ascorbic acid, °Brix, pH and viscosity.

In spite of the wealth of scientific data available on evaluating and comparing novel with traditional preserving technologies, most of the comparisons done were based on optimised and favouring conditions for one technology over another one (without considering a starting point for a fair basis comparison). Various equipment configurations and concepts were used, including mostly lab scale, evaluating changes immediately after the treatment, without taking into account eventual changes which may occur during storage. In addition, the advantage of continuous thermal preservation for pumpable products on industrial relevant equipment over in-pack (batch) thermal preservation has been neglected in most of the cases.

The general objective of this study can be summarised as the evaluation of traditional and novel large scale pasteurisation technologies (PEF and HPP) and refrigerated storage on the headspace fingerprint of tomato juice. The comparison between technologies was performed based on microbial equivalence. Moreover, pilot scale PEF processing system and industrial scale HPP unit were used in order to imitate industrial application. For the thermal treatment a pilot scale plate heat exchanger was used.

As a first step in finding key differences, a fingerprinting approach ('processomics') as a hypothesis-free starting point has been used. Volatiles are often involved in process- and storage-induced chemical reactions as intermediates or end products, which can directly impact foods' volatile profile, but also indicate what is happening in non-volatile fraction. Therefore, fingerprinting as an untargeted, multivariate and data-driven approach where as many compounds as possible are detected from a particular food extract can be considered as powerful tool for comparing processing impacts. Combined with appropriate multivariate data analysis, fingerprinting results in a selection of discriminative markers. These markers are selected compounds clearly different in concentration from one condition to the other, which should be further identified and linked to reaction pathways or particular food characteristics (Grauwet, Vervoort, Colle, Van Loey & Hendrickx, 2014). Based on this unbiased and fast screening approach, important reactions proceeding differently for different processing technologies can be suggested. Moreover, more insight in selected markers responsible for changes during shelf-life can be gained. The identification of the markers can be a first step towards process and product optimisation, as well as a starting point to set up further experimental kinetic studies.

2. Materials and methods

2.1. Tomato juice preparation

A 100 kg of tomatoes (*Solanum lycopersicum*, var. *Arvento*) obtained from a local store in Germany, were washed and crushed using a cutter (30 L VK 5000 express, Kilia Wertstoff-Technik GmbH, Germany). Shortly after crushing, vacuum has been applied to the freshly prepared juice to pull out air injected during chopping. The juice was packed in 5 and 10 litre plastic bags (side sealed PA/PE bags, Schulte&Co., Lohne, Germany) with as less as possible air inside, and stored at −40 °C until processing. Juice characteristics are presented in the Table 1.

2.2. Pasteurisation

Before processing, the juice was thawed at 4 °C. Since the objective of the current study was a fair-basis comparison, tomato juice was pasteurised by different processing technologies: thermal treatment, as a traditional treatment, and PEF and HPP as novel technologies; all three resulting in a comparable microbial inactivation. Processing conditions for all three pasteurisation technologies were selected as recommended by US Food and Drug Administration (FDA): a 5-log inactivation must be accomplished for the microbe identified as the "pertinent microorganism," which is the most resistant microorganism of public health significance that is likely to occur in the juice (FDA, 2004). In the pre-selection of pertinent microorganisms and selection of appropriate processing conditions for the current study in tomato juice, five different microorganisms (*Listeria innocua*, *Escherichia coli*, *Lactobacillus plantarum*, *Saccharomyces cerevisiae* and *Aspergillus niger*) were tested. From those five microorganisms *L. innocua* showed the highest resistance to PEF processing. Although tomatoes are not a

Table 1
Analytical parameters of freshly prepared tomato juice.

Parameter	Value
pH	4.05 ± 0.02
°Brix	4.69 ± 0.01
Conductivity (mS/cm)	4.82 ± 0.01
L*(D65)	33.94 ± 0.50
a*(D65)	11.85 ± 0.52
b*(D65)	7.90 ± 0.35