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Impact of different thermal preservation technologies on the quality of apple-based smoothies

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A B S T R A C T

Increased awareness of the importance of health promoting compounds in processed fruit products has led to the creation of novel products, such as smoothies, containing the majority of phenolics and fibre from fruits. It is important to evaluate the impact of traditional and modern thermal preservation methods on the quality of these novel products. Thermal treatment technologies (microwave flow, flow and batch pasteurization) were tested on apple-based smoothies of different composition: apple smoothies containing rosehip juice or wild blueberry juice. Smoothies with rosehip juice exhibited a higher total phenolics content than those with the addition of blueberry juice, but the differences were insignificant. Anthocyanins content measured in the smoothies with blueberry juice strongly depended on the preservation method used; the highest anthocyanins content was found in microwave preserved smoothies. Ascorbic acid content in the juices was the highest in flow-pasteurized juices (29 mg/100 g), while microwave treatment caused a significant decrease (20 mg/100 g). The effect of thermal processing on viscosity was also observed; microwave flow-pasteurized smoothies were characterized by higher viscosity and total pectins than those preserved by the other methods. This suggests that the preservation process interacts with microstructure and can affect smoothie quality during its shelf-life.
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1. Introduction

The process of society aging concerns practically all the countries in the world, but proceeds at a higher rate in the EU and the USA than in other countries. The share of elderly population (over the age of 60) in the world in 1990 was 9.2%, whereas in 2013 it went up to 11.7%, and is expected to reach 21.1% in 2050 (World Population Ageing: 1950–2050). Such changes in society were the driving force of the trend for « healthy aging « and the development of functional drinks designed for this specific population group. Apple is the most cultivated fruit in the EU and should naturally be considered as the base for healthy drinks, especially as a number of positive health recommendations for apples and products made from them can be found in the literature (Boyer & Liu, 2004). Most fruit and vegetable smoothies can fulfil the requirements set for the category of new functional drinks due to the high levels of antioxidants, minerals and soluble and insoluble fibre in them.

The health benefits of dietary fibre include the prevention and alleviation of type 2 diabetes, cardiovascular disease and colon cancer (Kaczmarczyk, Miller, & Freund, 2012). In smoothies, the pectins, non-starch polysaccharides (Lattimer & Haub, 2010) are the main component of soluble fibre. In the production of clear juices the pectins are completely removed, while in cloudy juices the levels of 0.2–1.3 g/l can be found (Markowski, Baron, Mieszczakowska, & Płocharski, 2009). The effect of intake of processed apple products on the cholesterol profile is in general positive, except for clear apple juice (Ravn-Haren et al., 2013). Taking the above into account, the technologies favouring the retention of pectins are strongly recommended for the processed products. Smoothies can be enriched with less known fruits which could push up the health value of these products; however, all these products have to be preserved by physical methods to ensure safety and a long shelf-life during marketing. Fruit juices, and in particular smoothies (these retain naturally occurring components, such as dietary fibre), are nutrient dense food, according to USDA (2016), and are offered in child nutrition programs (USDA, 2015), as part of the overall diet which, of course includes whole bread.

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Typical preservation of viscous products involves batch pasteurization, which, due to the thermal resistance of liquids and packaging, takes a long time. In contrast, flow pasteurization needs only a few seconds to raise the temperature to inactivate enzymes and kill microorganisms, which should improve the retention of heat-sensitive compounds. Considering the above, comparison was made of the standard batch pasteurization with two flow pasteurization methods: high temperature short time (HTST) pasteurization and innovative microwave flow pasteurization.

2. Experimental

2.1. Production

For the experiment, the 'Golden Delicious' apple cultivar was selected due to the fact that it is characterized by a good balance between the sugar content and acidity, and is available across Europe for fresh consumption and processing. The average soluble solids content of apples processed was 13.8 g/100 g, and acidity 0.51 g/100 g, resulting in the soluble solids:acidity ratio of 27. To investigate the degradation of heat-sensitive compounds such as ascorbic acid and anthocyanins, apple smoothies were suitably enriched with rosehip juice and blueberry juice.

In the production of cloudy juice, apples were ground with a Fryma perforated disc mill with a sieve having 6 mm diameter openings (BASIS 91/55, Fryma-Maschinen AG, Rheinfelden, Switzerland), with the addition of ascorbic acid (200 mg/kg), pressed using a rack and cloth press (Bucher, Niederweningen, Switzerland), and pasteurized with a plate heat exchanger (P20-VB, Alfa-Laval Food Engineering, Lund, Sweden) at 94 °C for 30 s. Apple purée was obtained by sieving fruit quarters blanched at 90 °C for 3 min through a pulper machine with 1 mm stainless steel sieve (Spomasz, Toruń, Poland). The hot purée was deaerated under vacuum. Both the cloudy juice and purée were kept frozen until processing. Smoothies were produced by mixing the apple purée (500 g/kg) with the cloudy apple juice and rosehip juice (400 and 100 g/kg, respectively) or wild blueberry juice (300 and 200 g/kg). The rosehip and wild blueberry juices were produced and supplied by Polska Róża processing company. The mixtures were disintegrated using a Fryma colloid mill (Fryma Rheinfelden, Type 20–80, Switzerland) and heat processed. Glass bottles (0.25 L) were used for filling each batch of the products. The control samples were batch-pasteurized by immersing bottles in cold water, holding them for 20 min after reaching 90 °C, followed by cooling down in tap water. The second batch was flow-pasteurized with a tubular heat exchanger (P90, Voran Maschinen GmbH, Pichl bei Wels, Austria) at a temperature of 94–96 °C for 40 s, hot-filled into bottles and immediately cooled in tap water. The conditions of the heat treatments assured microbial stability (The Food Processors Institute, 1988). The third batch was microwave flow-pasteurized using Enbio Jet equipment (Enbio Technology, Suchy Dwór, Poland) at parameters set up by the staff of the Enbio company, and cooled immediately after filling the bottles. The experiments were conducted in two technological replications for each treatment.

2.2. Analyses

Anthocyanins (ANT) were determined by the pH differential method (Giusti & Wrolstad, 2001). The ANT content was calculated using cyaninin-3-glucoside with molar absorptivity of 29,600 at 541 nm and molecular weight of 442.2.

Ascorbic acid (ASC) was determined after homogenizing samples with an Ultra Turrax T 25 homogenizer (Ika-Werke, Staufen, Germany) in 60 g/L meta-phosphoric acid water solution, using HPLC HP 1200 (Hewlett-Packard, Waldbronn, Germany) with a DAD detector and two LC-18 columns (25 cm × 4.6 mm) connected in series, particle size 5 μm (Supelco, Bellefonte, PA, USA). 10 g/L KH_2PO_4 buffer at pH 2.5 was used as the mobile phase at 30 °C, with a flow rate of 0.8 ml/min. Detection of ASC was at 254 nm, and a bandwidth of 6 nm. Before injection, the samples were filtered through 0.45 μm nylon filters.

β-carotene was determined by the HPLC method described by Bohoyo-Gil, Dominques-Valmondo, Garcja Parra, and Gonzalez-Gomez (2012), using an HP 1200 (Hewlett-Packard, Waldbronn, Germany) and a Kinetex C18 100A (250 mm × 4.6 mm) column (Phenomenex, Torrence, USA). Detection of carotenoids was at 450 nm, and a bandwidth of 6 nm. The LOD of carotene was 0.12 μg/100 g.

Total phenolics content (TPC) was determined by the Folin-Ciocalteu colorimetric method (Tsao & Yang, 2003). The absorbance was read at 765 nm. TPC was calculated against gallic acid.

Total pectins (TP) and water-soluble pectins (WSP) were determined with an IFU 26 (Anonymous, 2008) by ethanol precipitation and reaction with carbazole in sulphuric acid.

Insoluble fibre (IDF) & soluble fibre (SDF) were determined according to AOAC 991.42, using a Megazyme K-TDFR test kit and Foss Fibertec (Fibertec™ 1023, Höganäs, Sweden). **Total dietary fibre (TDF)** was the sum of the two forms of fibre.

Viscosity was determined with a Brookfield LV-DVII + viscometer (Brookfield Eng., Middleboro, USA) with no. 3 spindle at 60 rpm; the procedure of sample stabilization and preparation was according to ASTM D 2196-86.

2.3. Statistics

A two-way ANOVA and Duncan's multiple range test at $P = 0.05$ were used to compare the mean values of the data. The statistical analyses were conducted with Statistica 8.0 (StatSoft, Tulsa, USA). The mean values represent two independent technological replications of juice production methods.

3. Results and discussion

The data concerning the basic qualities of the juices are presented in Tables 1 and 2.

Smoothies with added wild blueberry juice contained 13–18 mg/100 g anthocyanins. For this unstable group of phenolics, microwave flow pasteurization was the best thermal treatment technology. The highest anthocyanins content of 17.7 mg/100 g was found in microwave-preserved blueberry smoothies, while in the batch-pasteurized control samples there was only 12.8 mg/100 g (Table 1). By contrast, the other unstable compound, ascorbic acid, was the highest in flow-pasteurized juices (29 mg/100 g), while the microwave treatment surprisingly resulted in a post-process value of 20 mg/100 g. This is at variance with literature data (Igual, Garcia-Martinez, Camacho, & Martinez Navarette, 2010) and suggests that for a better comparison of these technologies more investigation concerning the measurement of microwave heat load and the time-temperature profile should be performed.

Literature data indicate that β-carotene and its isomers are stable during heat treatment (Provesi, Dias, & Amante, 2011), and this was the case with the carotenoids originating from the wild rose hip juice (Table 1); irrespective of the treatment, the average value was 0.35 μg/100 g of the product.

The total phenolics content was in general not influenced by the thermal treatment method used (Table 1), and the average amount of phenolic compounds in the smoothies was 150 mg/100 g; this is in agreement with the average value for 48 smoothies available on the German market (Reißaus et al., 2011).

The characteristics of the different forms of dietary fibre are

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