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Change regime of aroma active compounds in response to pulsed electric field treatment time, sour cherry juice apricot and peach nectars, and physical and sensory properties

Gulsun Akdemir Evrendilek *

Department of Food Engineering, Abant Izzet Baysal University, Bolu, Turkey

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ABSTRACT

Regime (direction, amount, rate, and pattern) of change in aroma active compounds was quantified as a function of four pulsed electric field (PEF) treatment times, three fruits, and 10 physical and eight sensory properties using the best-fit multiple linear regression (MLR) models. The PEF treatment times did not deteriorate 94% of the sensory properties and 70% of the physical properties and significantly change 57% of a total of 73 aroma active compounds detected for sour cherry juice, and apricot and peach nectars. The best performing MLR models belonged to 1-methyl-4-prop-1-en-2-ylcyclohexene as a function of fruit type, treatment time, and titratable acidity ($= 49$ mg/L; $R^2_{\mathrm{adj}} = 95.7\%$; $R^2_{\mathrm{cv}} = 94.9\%$) and to 2-[(2S,5S)-5-ethenyl-5-methyloxolan-2-yl]propan-2-ol as a function of fruit type, and treatment time (SE $= 157$ mg/L; $R^2_{\mathrm{adj}} = 98.2\%$; $R^2_{\mathrm{cv}} = 98.0\%$), respectively ($n = 48$; $p < 0.001$).

Industrial relevance: Pulsed electric field (PEF) is one of the leading nonthermal food technologies especiallyfor processing of high acid low viscosity foods with satisfactory quality and microbial inactivation. It was shown in this study that PEF with different treatment times can successfully be applied in the pasteurization of sour cherry juice, and apricot and peach nectars with minimum loss of aroma active compounds and sensory and physical properties. Both PEF processing conditions and results can be used as a guide to determine PEF processing parameters for industrial scale processing of juices/nectars.

1. Introduction

Application of thermal and non-thermal food processing technologies strives to preserve safety, nutritional quality, and sensory characteristics of juices. In particular, recent foci have been placed on the preservation of flavor and aroma characteristics as both of them are the two most appealing characteristics of fruit juices that play an important role in consumer preference. As food processing and storage conditions have been reported to adversely affect aroma profile of juices (Horwat & Chapman, 1990; Rios de Souza et al., 2014; Vavoura, Badeka, Kontakos, & Kontominas, 2015; Visai & Vanoli, 1997), non-thermal alternative technologies have been used to process juices to minimize the degradation of aroma profile with a fresher taste. The concentrations of aroma compounds in fresh and processed fruit products have been reported to depend on environmental, biotic, harvesting and postharvest processing factors and to have a direct impact on their sensory quality. The relationships of aroma compounds with perceived sensory properties and physicochemical properties have been studied for different fruit products but for peach and apricot nectars and sour cherry juice. For example, 2-propanone as a carbonyl compound was found to be the most important aroma compound of four sweet cherry cultivars grown in Greece and to have a strong negative correlation with titratable acidity regardless of the cultivar type and a strong correlation of a changing direction with texture depending on the cultivar type (Vavoura et al., 2015). The increased electrical conductivity, total soluble solids, acids, sugars and aroma volatiles of fruits were reported to essentially determine their overall taste and flavor (Serradilla et al., 2012).

Processing of fruit juices with the application of pulsed electric fields (PEFs) is one of the non-thermal alternative technologies with the great potential for microbial and enzyme inactivation, shelf-life extension, and preservation of nutritional and sensory properties, and aroma compounds. For example, Jia, Zhang, and Min (1999) reported that PEF-processed orange juice (30 kV/cm, either at 240 or 480 μs) resulted in no significant change in the initial decanal and octanal concentrations, whereas heat treatment (90 °C for 3 min) decreased the initial decanal and octanal concentrations by 40 and 9.9 %, respectively (Jia et al., 1999). Additionally, degradation of butanoic acid was found to be significantly less by PEF treatment than by heat processing (Jia et al., 1999). Aguilar-Rosas, Ballinas-Casarrubias, Nevarez-Moorillon, Martin-Belloso, and Ortega-Rivas (2007) showed that PEF retained most of the volatile compounds responsible for color and flavor of apple juice

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* Tel.: +90 374 2534640; fax: +90 374 2534558.
E-mail address: gevrendilek@ibu.edu.tr.

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better than heat treatment and caused 7% and 8.4% losses of hexanal and hexyl acetate, respectively, unlike heat treatment which caused their complete losses (Aguilar-Rosas et al., 2007).

Although PEF processing of sour cherry juice, and apricot and peach nectars was conducted to determine its inhibitory effect on foodborne and plant borne pathogens as well as changes in physical properties in the related literature (Altuntas, Evrendilek, Sangun, & Zhang, 2010, 2011; Evrendilek, Altuntas, Sangun, & Zhang, 2013; Evrendilek, Tok, Soylu, & Soylu, 2008, 2009), the previous studies did not quantify PEF-induced changes in aroma active compounds. Therefore, the objective of this study was to characterize and model direction, amount, rate, and pattern of changes in aroma active compounds as a function of PEF-treated sour cherry juice and apricot and peach nectars, treatment time, and physical and sensory properties.

2. Materials and methods

2.1. Fruit juice and nectars

Freshly squeezed sour cherry juice (SCJ), and peach (PN) and apricot nectars (AN) were obtained from Dimes Gıda San. & Tic. Anon. Sti. (Tokat, Turkey) and were immediately processed using PEF.

2.2. Pulsed electric field (PEF) treatments

The fruit juice and nectar samples were processed using a bench-scale continuous PEF system (OSU 4A, The Ohio State University, Columbus, OH, USA). Square wave bipolar pulses with 3 μs duration and 20 μs delaying time were applied at a 50-mL/min flow rate. A total of six treatment chambers with 0.29 cm diameter and 0.23 cm gap distance were used. PEF processing was conducted using 125, 250 and 400 Hz frequencies under the electric field strength of 24 kV/cm. When 125 Hz frequency was applied, the total treatment time was 66 μs with the energy input of 8.4 J/s. Application of 250 and 400 Hz frequencies resulted in 131 and 210 μs total treatment times and 16.8 and 26.9 J/s energies, respectively. To control temperature increases during PEF treatments, a cooling coil system immersed in a water bath at 10 °C was adopted before and after each pair of the treatment chamber. Treatment temperature was measured during the PEF processing before and after each pair of the PEF treatment chamber (t_1, t_2, t_3, t_4, t_5, and t_6) using K type dual channel digital thermocouples (Fisher Scientific, Pittsburgh, PA, USA).

2.3. Analysis of physical properties

Ten mL of samples was taken for pH measurements conducted at room temperature (Orion PerpHecT logR meter, Inolab WTW, Germany). Five mL of the samples was used for titratable acidity measurements (TA, %) and was titrated with 0.1 N NaOH after the addition of 0.5 mL phenolphthalein until pH reached 8.1. Total soluble solids (°Bx) of the samples at room temperature were measured using a 507-1 model hand-held refractometer (Nippon Optical Works Co. Ltd., Japan). Electrical conductivity (EC) measured using a hand held conductivity meter (Sension 5 model, HACH, CO, USA) was expressed in mS/cm. Color measurements of L*, a* and b* were performed using a Hunter Color Flex spectrophotometer (Hunter Associates Laboratory Inc., Reston, VA, USA) according to the CIELAB color scale at D65/10°.

Prior to the measurement of non-enzymatic browning index (BI), the samples were centrifuged at 9418 ×g for 5 min (Hettich Universal 32R D78532 model, Germany) to remove pulp and coarse cloud particles. Supernatant was collected and clarified using a 0.45 μm filter (Gelman Sciences, Ann Arbor, MI, USA). Absorbance was measured at 420 nm (Perkin Elmer Lambda 25 model, MA, USA) at room temperature.

2.4. Analysis of total ascorbic acid content (TAAC)

A high-performance liquid chromatography (HPLC) system (Shimadzu LC-10AT VP model, Kyoto, Japan) equipped with manual injection port and a detector (Shimadzu, Kyoto, Japan) at 254 nm was used to determine total ascorbic acid content (TAAC). The HPLC system was equipped with a SPD-M20A Prominence Diode Array Detector (DAD) (Shimadzu, Kyoto, Japan) to calculate the chromatograph peak area. A reverse-phase C-18 column (5 μm particle size, 4.6 mm diameter, 250 mm length, Agilent Technologies, Cheshire, UK) along with a Hewlett-Packard C-18 guard column was used to separate vitamin C using methanol and acidified water (10:90 v/v) with phosphoric acid (0.01 % v/v) as a mobile phase. The mobile phase was filtered using a 0.45 μm membrane filter (Micron Separations Inc., Westborough, MA, USA) and degassed using helium gas before passing through the column at a flow rate of 1.0 mL/min. A standard calibration curve was obtained using ascorbic acid (Sigma Chemical Co., Stockholm, Sweden) in concentrations ranging from 5 to 80 mg/100 mL. Five mL of the samples was transferred into test tubes, and 5 mL of 25% m-phosphoric acid was added. The supernatant (0.5 mL) was removed after the centrifugation of the samples at 9418 ×g for 5 min. The sample volume was completed to 10 mL with 25% m-phosphoric acid, filtered through 0.45 μm filter, and 20 μL of the sample was injected into the column using the HPLC injection port (Yeom, Streaker, Zhang, & Min, 2000).

2.5. Analysis of total beta carotene content (TBC)

Total beta carotene content (TBC) was determined in both apricot and peach nectar samples using an HPLC equipped with a reverse phase S10 ODS2 column (5 μm particle size, 250 mm length, 4.6 mm diameter) (Phase Separations, Spherisorb ODS2, Clwyd, UK). Mobile phase was a mixture of acetonitrile/dichloromethane/hexane/methanol mixture at 40/25/25/10 (v/v) ratio and was filtered through a 0.45-μm syringe filter before being fed into HPLC at a flow rate of 1 mL/min with the presence of detector working at 450 nm. β-Carotene (Sigma, Germany) in the concentrations of 5, 10, 30, 40, 50 and 80 ppm was used to draw the standard curve. Prepared samples were centrifuged at 9418 ×g for 4 min, and 20 μL of the supernatant was injected into HPLC for analyses (Lee, Chua, Ong, & Ong, 1992).

2.6. Analysis of total monomeric anthocyanin content (TMAC)

TMAC was measured only for sour cherry juice using the pH differential measurements. After the samples were diluted with 0.025 M KCl (Sigma Chemical Co., Stockholm, Sweden) and 0.04 M Na-acetate (Sigma Chemical Co., Stockholm, Sweden) at the ratio of 1 to 20, separately, the mixtures were centrifuged at 2400 rpm for 2 min by vortex. The samples were set for 20 min, and both dilutions were read at both 520 and 700 nm using a spectrophotometer (Perkin Elmer Lambda 25 model, MA, USA). Absorbance readings were carried out against water blanks. Results were expressed in mg/L as cyanidin 3-glucoside-equivalent and were calculated as follows (Sutharut & Sudarat, 2012):

$$A = (A_{520} - A_{700})_{\mathrm{pH}\,1.0} - (A_{510} - A_{700})_{\mathrm{pH}\,4.5}$$

$$TAC(\mathrm{mg/L}) = \left(A \times M_W \times DF \times 10^3\right) / \varepsilon \times l$$

where A is the total absorbance; M_W is the molecular weight of anthocyanin (449 g/mol); DF is the dilution factor; ε is the extension coefficient (29600 L/cm mol); 10^3 is the factor for conversion from g to mg; and l is the path length (1 cm).