Food Research International 82 (2016) 22–33

Contents lists available at ScienceDirect

Food Research International

journal homepage: www.elsevier.com/locate/foodres

Peach juice processed by the ultrasound technology: Changes in its microstructure improve its physical properties and stability

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ARTICLE INFO

Article history:
Received 2 December 2015
Received in revised form 11 January 2016
Accepted 15 January 2016
Available online 18 January 2016

Keywords:
Fruit juices
Ultrasound technology
Physical stability
Physical properties

ABSTRACT

Ultrasound is a non-conventional processing technology, which can be used not only for food preservation, but also to improve its properties and quality. This study evaluated the physical properties and stability of peach juice processed by the ultrasound technology. The peach juice processed by the ultrasound technology showed changes in its structure, evidenced by the optical microscopy and particle size distribution, involved steps of cell damage and release of intracellular content, particle size reduction, disruption of the whole cells, polysaccharide size reduction and dispersion of constituents. These effects, depending of the processing time, can trigger different mechanisms with a complex behaviour. The interaction among them and the relative importance of each one change during processing, determining the final rheological properties, pulp sedimentation and serum cloudiness (turbidity). The results indicated that the ultrasound technology can be used to improve the physical properties of peach juice, increasing the stability to pulp sedimentation and serum cloudiness, maintaining or increasing the juice consistency, with insignificant colour changes during the storage.

1. Introduction

Ultrasound (US) is defined as sound waves having frequency that exceeds the limit of the human ear (~20 kHz). This technology has been used as alternative to conventional food processing. Based on the frequency range, the applications of ultrasound in food analysis, quality control and processing can be divided into low energy (frequencies higher than 100 kHz at intensities below 1 $W \cdot cm^{-2}$,) and high energy (intensities higher than 1 $W \cdot cm^{-2}$ at frequencies between 20 and 500 kHz) (Awad, Moharram, Shaltout, Asker, & Youssef, 2012). The use of power ultrasound (high energy) in processing, which due the acoustic and hydrodynamic cavitations are able to induce chemical and physical changes in different food systems (Awad et al., 2012; Chemat, Zill e, & Khan, 2011). In fluid food systems, such as juices, subjected to sonication, a number of physical and mechanical effects can result. Large particles of a liquid suspension are subject to surface erosion (by cavitation collapse in the surrounding liquid) or particle size reduction (due to fission through interparticle collision or the collapse of cavitation bubbles formed on the surface) (Mason, Paniwnyk, & Lorimer, 1996). Several studies have evaluated the use of the US technology as alternative for fluid food processing facilitating operations such as emulsification (Gaikwad & Pandit, 2008), modifying the functional properties of different food proteins (Yanjun et al., 2014) and assisted the extraction of various food and bioactive compounds (Barba, Brianceau, Turk, Boussetta, & Vorobiev, 2015; Roselló-Soto et al., 2015).

In fact, many works were carried out relating the processing of fruit juices using the US technology as alternative for total or partial substitution of thermal processing (Zinoviadou et al., 2015). Thermosonication with low temperature could enhance the inactivation of enzymes and microorganisms and it was used as a potential preservation technique in pear juice (Saeeduddin et al., 2015), tomato juice (Ertugay & Başlar, 2014; Terefe et al., 2009; Wu, Gamage, Vilkhu, Simons, & Mawson, 2008), watermelon juice (Rawson et al., 2011), orange juice (Walkling-Ribeiro, Noci, Cronin, Lyng, & Morgan, 2009), apple juice (Abid et al., 2014; Baslar & Ertugay, 2013), grapefruit juice (Aadil et al., 2015), among others.

At present, the effect of US technology on the physical properties of food products such as the colour degradation and quality parameters in orange juice (Tiwari, Muthukumarappan, O'Donnell, & Cullen, 2008; Tiwari, O' Donnell, Muthukumarappan, & Cullen, 2009), cloudy quality of apple juice (Ertugay & Başlar, 2014), colour stability and apparent viscosity of pineapple juice (Costa et al., 2013), colour stability, solid deposition and apparent viscosity of cactus pear (Cruz-Cansino et al., 2015), colour and sensory quality (appearance, texture, taste and aroma) of soursop juice (Dias et al., 2015), has been studied. These previous works indicated that this technology could be used to increase and improve the properties of juices such as the consistency (apparent viscosity), colour, cloudy stability and its sensory acceptance.

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http://dx.doi.org/10.1016/j.foodres.2016.01.011
0963-9969/

However, it is still necessary to improve the description of how the US technology promotes desirable physical properties of fruit juices widely consumed nowadays. Further, the mechanisms by which the US technology changes the food properties must be described, as well as correlate the process with the food structure and properties. In fact, it is expected that the US technology could prevent the pulp sedimentation by disrupting the suspended particles, reducing the need for addition of stabilizers to the juice, which is highly desirable from an industrial point of view.

Therefore, the present work evaluated the effect of the US technology on the physical stability of peach juice, evaluating the changes in its microstructure, particle size distribution (PSD), pulp sedimentation, serum cloudiness, juice colour and rheological properties of the peach juice and peach serum.

2. Materials and methods

2.1. Peach juice

In order to guarantee standardization and repeatability, a commercial pasteurized peach pulp (DeMarchi, Brazil) was used to obtain the peach juice. From then, the pulp was diluted in distilled water using 50% of pulp, according to the Codex Alimentarius (2005). The characteristics of the prepared juice were pH of 4.36 ± 0.02 and 4.05 ± 0.08% of total solids and 3.00 ± 0.00 °Brix As established in the Codex Alimentarius (1995) and described in previous work (Kubo, Augusto, & Cristianini, 2013), potassium sorbate (1000 mg·kg^{-1}) was added to the peach juice in order to allow microbial stability during the 21-day of storage evaluation at 25 °C.

For the rheological study of the continuous phase (juice serum), the juice prepared as described above was stored for 24 h at 5 °C (Biplex fridge 340 L, Consul, Brazil) in order to guarantee the complete pulp hydration. Then, the serum was obtained by centrifugation of the juice at 3300*g* for 10 min at 25 °C (ROTINA 420 R refrigerated centrifuge, Hettich, England).

2.2. Ultrasonic processing

The peach juice sample (150 mL) was placed in a jacketed vessel with water circulation in order to control the process temperature (the temperature of all processing times was maintained at 22 ± 3 °C). The samples were processed at five processing times (0, 3, 6, 10 and 15 min — these conditions were fixed at previous evaluation) using an ultrasonic tip (ECO-SONIC, QR1000 Model, Brazil) with a nominal power of 1000 W, frequency of 20 kHz and a 1.26 cm^2 titanium tip (keeping it at 3 mm depth in the juice samples — manufacturer recommendations). The ultrasonic intensity and volumetric power of the equipment were 793.65 W/cm^2 and 6.67 W/mL, respectively. Therefore, the energy inputs was 0 kJ/mL for the control sample (0 min of ultrasonic processing), and for the treatments of 3, 6, 10 and 15 min it was 1.20, 2.40, 4.00 and 6.00 kJ/mL, respectively. All the treatments were carried out in triplicate.

2.3. Effect of the ultrasound technology on peach juice microstructure, physical properties and stability

The effect of US on the juice properties was evaluated from its microstructure (using both optical microscopy and particle size distribution (PSD) evaluation), pulp sedimentation, serum cloudiness, juice colour, and rheological properties (time-dependent and steady-state shear properties of the juice and serum). The unprocessed sample (coded as US-0 min) and the processed samples (coded as US-3 min, US-6 min, US-10 min, US-15 min) were compared just after processing and during 21 days of storage at 25 °C (B.O.D. TE391, Tecnal, Brazil), in order to understand the effect of the US on the physical stability of the juice. The analyses were carried out with three replicates.

2.3.1. Optical microstructure

The samples (~20 μL) were deposited and dispersed on a glass slide to be observed under an optical microscope (Olympus system microscopy model BX41, Japan) equipped with a digital colour camera (Q-Color 3 OLYMPUS America INC, including the SQ Capture 2.90.1 Ver. 2.0.6 Software, Canada). The images were captured at least in quintuplicate for each sample using the 10× objective.

2.3.2. Particle size distribution (PSD)

The PSD of juice was determined using the Laser Diffraction Particle Size Distribution Analyzer (Partica LA-950V2 Laser Particle Size Analyzer HORIBA, Japan). Data obtained were analysed using the equipment software (HORIBA LA-950 for Windows, Japan).

In addition to the PSD, the volume-based mean diameter (D[4,3] Eq. (1)), and the area-based mean diameter (D[3,2], Eq. (2)), were evaluated. Both equivalent diameters were evaluated since the D[4,3] is highly influenced by large particles whereas D[3,2] is more influenced by the smaller ones (Bayod, Mansson, Innings, Bergenstahl, & Tornberg, 2007; Bengtsson & Tornberg, 2011; Schultz, Barrett, & Dungan, 2014; Zhang, Wang, Zhou, & Liao, 2010).

$$D[4,3] = \frac{\sum_i n_i d_i^4}{\sum_i n_i d_i^3} \quad (1)$$

$$D[3,2] = \frac{\sum_i n_i d_i^3}{\sum_i n_i d_i^2} \quad (2)$$

2.3.3. Pulp sedimentation

Pulp sedimentation was evaluated using 25 mL graduated cylinders filled with the samples and stored at 25 °C (BOD TE391, Tecnal, Brazil) for 21 days (simulating a shelf life evaluation). The evaluation was carried out every day during the first 6 days and further five times during the next 15 days. In addition, during the first day, it was carried out the evaluation of sedimentation in the first 24 h in order to understand the juice sedimentation behaviour during the moment to be consumed. As described by Kubo et al. (2013), Leite, Augusto, & Cristianini (2015) and Silva et al. (2010)) the sedimentation index (IS in %) was obtained according to Eq. (3).

$$IS\% = \frac{S_{(t)}}{V} \cdot 100 \quad (3)$$

2.3.4. Serum cloudiness (turbidity)

The serum cloudiness was also evaluated during the storage. For that, aliquots (6 mL) of the stored juice were centrifuged at 3300*g* for 10 min at 25 °C (ROTINA 420 R refrigerated centrifuge, Hettich, England). The supernatant (i.e., the juice serum) was poured into 3 mL cuvettes and placed in a UV–visible spectrophotometer (Uvmini-1240, SHIMADZU, Japan) calibrated with distilled water. The absorbance at 660 nm was measured and directly related to the turbidity (Kubo et al., 2013; Liang et al., 2006; Silva et al., 2010; Zhang et al., 2010; Zhou, Zhang, Leng, Liao, & Hu, 2010).

2.3.5. Instrumental colour

The instrumental colour was measured using a Hunter Lab spectrophotometer (MiniScan® XE Plus, Hunter associates Laboratory Inc., USA), using the D65° illuminant with an angle of observation of 10°. For the analysis, 50 mL of juice sample at 25 °C was used. The samples were placed in glass cuvette, and three readings were obtained for each replicate. The colour was recorded using the CIE (*Commission Internationale d'Eclairage*) colour scale to measure the parameters of L*,