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Non-thermal combined treatments in the processing of açai (*Euterpe oleracea*) juice

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ABSTRACT

Quality parameters of açai juice processed with ultrasound-assisted, ozone and the combined methods were analyzed in this work. Two ultrasound energy densities (350 and 700 J·mL^{-1}) and two ozonization times (5 and 10 min with 1.5 ppm) were analyzed for pure açai juice and 8 different treatments (2^2 complete factorial). To evaluate the quality parameters of the juice, physical-chemical analyzes such as pH, titratable acidity, cloud value, non-enzymatic browning, rheology, antioxidant activity (DPPH and ABTS), phenolic compounds, anthocyanins, enzymatic activity (peroxidase and polyphenol oxidase) and microbial counts (mesophilic bacteria, molds and yeasts) were conducted. The treatments with ozone were better for microbial inactivation and the ultrasound for enzymatic inactivation. In general, the use of non-thermal methods can be a good alternative for the processing of açai juice.

1. Introduction

Açai (*Euterpe oleracea*) is one of the best-known fruits of the Amazonian bioma with great economic, nutritional and technological potential. It is a fruit with high concentrations of bioactive compounds like anthocyanins and phenolic compounds, with great antioxidant activity. Its high perishability requires additional processes to increase its shelf life and improve its stability (Tonon, Brabet, & Hubinger, 2010).

In fruit juice processing, thermal technologies such as pasteurization and sterilization are commonly used, successfully reaching microbial food safety goals, but the combination of time and temperature in these techniques is directly related to loss of phytonutrients, organoleptic properties and development of some other undesirable changes in fruit juices (Abid et al., 2013). From this, numerous researchers are studying the use of new food processing and preservation technologies, especially those that use milder process temperatures. In this context, the processing of fruit juices with ultrasound and ozone present potential in the conservation of the physical-chemical characteristics of these foods, guaranteeing microbiological safety and stability (Rodrigues & Fernandes, 2015).

Ultrasound-assisted fruit juice processing involves the use of mechanical ultrasonic energy in the inactivation of degrading enzymes and microorganisms. Ultrasound-assisted processing has several advantages such as minimization of taste, color and bioactive compound losses; energy efficiency and greater process homogeneity (do Rosário et al., 2017). Several studies have already demonstrated the efficiency of ultrasound-assisted processing in fruit juice processing (Aadil, Zeng, Han, & Sun, 2013; Santos, Rodrigues, & Fernandes, 2018).

Another important technique in the processing of fruits is ozonization, which consists of using ozone gas for the purpose of reducing the microbial load (Fundo, 2018). The resulting destruction or lysis associated with ozone is a faster inactivation mechanism than other disinfectants, which require the disinfectant to permeate through the cell membrane to be effective (Cullen, Tiwari, O'Donnell, & Muthukumarappan, 2009). The literature presents few studies on the

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use of ozone gas in the sanitation of fruit juices (Fundo et al., 2018; Jaramillo-Sánchez, Garcia Loredo, Gómez, & Alzamora, 2017; Jaramillo Sánchez, Garcia Loredo, Contigiani, Gómez, & Alzamora, 2018; Miller, Fundo, Silva, & Brandão, 2018).

Ultrasound processing and ozone are emerging technologies, recognized for being effective in obtaining various foods, reducing or even eliminating microorganisms, and improving the processing conditions of many products, taking into account new market trends. As emerging technologies, there is a need for in depth studies for their employment, seeking a better standardization and quantification. The use of combined non-thermal methods in food preservation may (1) increase the lethal effects of non-thermal processing, (2) reduce the severity of the non-thermal treatment required to achieve a certain level of microbial and/or (3) to prevent the proliferation of surviving microorganisms after treatment (Asokapandian, Periasamy, & Swamy, 2017).

From the above, this work had the objective of studying the use of two techniques of non-thermal processing (ultrasonic-assisted and ozone gas) in the processing of açai juice. Analyses were conducted of pH, titratable acidity, cloud value, enzymatic darkening index, conductivity, viscosity, bioactive compounds (DPPH, ABST, phenolic compounds and anthocyanins), bacterial counts, molds and yeasts and enzymatic activity (peroxidase and polyphenol oxidase) for the acai juices treated at different levels of ultrasound energy density, ozone concentration or the combined methods.

2. Materials and methods

2.1. Preparation of açai juice

Açai pulp (*Euterpe oleracea*) was purchased locally. The pulp was homogenized in an industrial blender with 1:1 (w/w) water. The solution was filtered through polyester fabric to remove larger particles and fibers. The juice was stored in glass bottles at a temperature of -18 °C until the analyzes were carried out.

2.2. Ultrasound-assisted treatment

An ultrasonic equipment (model DES500 500W, Unique, Brazil) with a probe of 1.3 cm in diameter was used to sonicate the juice. The samples were processed at a constant frequency of 19 kHz. 100 mL aliquots of açai pulp were placed in glass beakers and sonicated at 5 min constant times. The probe was submerged to a depth of 25 mm in the sample and every procedure was performed with an ice bath to avoid heating the juices and consequently the degradation of compounds by heat (Processing temperature: 32 ± 1.2 °C) (Fig. 1).

2.3. Ozone treatment

For the samples with ozone application (Fig. 1), the açai juice (100 mL) was placed in a beaker with constant agitation of 100 rpm and with direct immersion of ozone gas (Podoxi model, Interozone Brasil Group) for 5 or 10 min. The ozone concentration (1.50 ppm) was kept constant during the treatment time. The ozone concentration was measured by iodine metrical (Beber-Rodrigues, Savi, & Scussel, 2015). After the ozonation, the juice samples remained under magnetic stirring for 1 h and 6000 rpm until total elimination of the residual gas. Samples were evaluated at 25 °C.

2.4. Experimental design

The experiment was designed for a completely randomized design from pre-test results. The juice samples were submitted to different non-thermal treatments as described in Table 1. The Energy density (ED) can be obtained by Eq. (1):

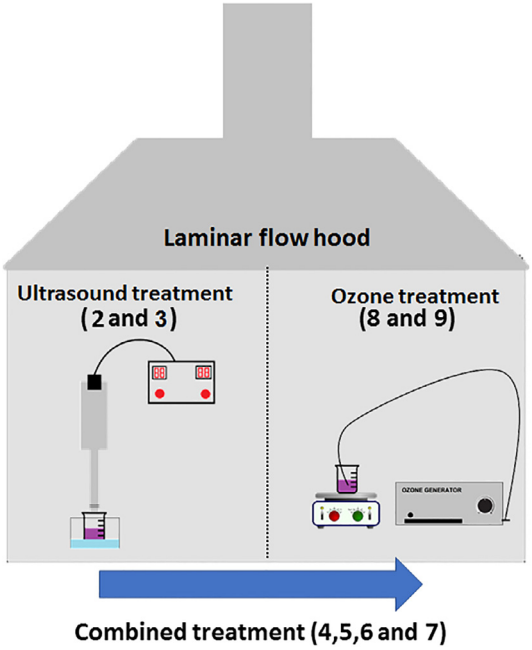

Fig. 1. Experimental setup of açai juice treatments.

Table 1
Experimental design of açai juice.

Assay	Ultrasound-assisted ($J{\cdot}mL^{-1}$)	Ozonization (min)
1 (control)	0	0
2	350	0
3	700	0
4	350	5
5	700	5
6	350	10
7	700	10
8	0	5
9	0	10

$$ED = \frac{P \times t}{V} \quad (1)$$

where P is the Power delivered to the system (W); t is the sonication time (s) and V is the volume of the fluid (mL).

2.5. pH and titratable acidity

The pH of açai juice sample was measured using a digital pH meter (model PHS3BW, Bell, Brazil). Ten mL of sample was placed in a beaker and stirred continuously with a magnetic stirrer. Titratable acidity (TA) was determined by (Abid et al., 2013). The volume of NaOH was converted to the amount of malic acid (gram) per 100 mL of juice and titratable acidity was then calculated by using the following Eq. (2):

$$TA(\%) = \frac{VT \times N \times AF \times 100}{SV} \quad (2)$$

where: VT is volume of base titrant; N is normality of base; AF is acid factor and SV is sample volume.

2.6. Cloud value and non-enzymatic browning

Cloud value and non-enzymatic browning of açai juice were determined according to methods by Aadil et al. (2013). For cloud value, a sample of 5 mL was centrifuged at 3000 rpm for 10 min at 20 °C with a centrifuge. Cloud value was determined as the supernatant absorbance at 660 nm using a spectrophotometer with distilled water serving as a