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Ohmic Heating: A potential technology for sweet whey processing

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ABSTRACT

The use of Ohmic Heating (OH) for sweet whey processing was investigated in this study. Whey samples were subjected to both different OH parameters (2, 4, 5, 7 and 9 $V \cdot cm^{-1}$ at 60 Hz, up to 72–75 °C/15 s) and conventional processing (72–75 °C/15 s). Physicochemical analyses (pH), color measurements (L^*, a^*, b^*), rheological properties (flow curves and particle size distribution), microstructure (optical microscopy), bioactive compounds (ACE and antioxidant capacity), microbiological characterization (mesophilic bacteria, total coliforms, and thermotolerant coliforms), water mobility (TD-magnetic resonance domain), and sensory evaluation (descriptive analysis) were carried out. The OH effects on sweet whey characteristics depended on the applied electric field intensity. Higher saturation, higher color variation (ΔE^*), and higher luminosity (L^*) were observed in low electric fields. For bioactive compounds, the increase of the electric field negatively affected the preservation of the antioxidant capacity and the ACE Inhibitory Activity of bioactive peptides. OH and conventional samples exhibited a pseudo-plastic behavior ($n < 1$). OH performed at 4 and 5 $V \cdot cm^{-1}$ was able to provide similar levels of sensory profile and higher volatile compounds levels. The results suggested the OH technology as an interesting alternative to whey processing.

1. Introduction

The whey produced in cheese making is a value-added by product that is widely used in the enrichment of food products, containing proteins with important functional properties when hydrolyzed, such as antioxidant and antihypertensive properties (Brandelli, Daroit, & Corrêa, 2015; Pate, 2015). However, these properties may undergo drastic modifications during thermal processing, thus changing the protein structure, such as protein denaturation and aggregation, protein-protein interactions (Roux et al., 2016), and browning reactions, such as Maillard reaction (Kim & Kang, 2015), causing great impact on the quality of the final product.

Among the emerging methods of food processing, Ohmic Heating seems to be an interesting alternative for dairy production (Cappato et al., 2017) as it provides fast and uniform heating, minimizing the generation of off-flavor compounds and providing minor changes in nutrients, when compared to the conventional heat treatment (Pataro, Donsì, & Ferrari, 2011), besides guaranteeing the microbiological safety of the product (Pereira, Martins, Mateus, Teixeira, & Vicente, 2007). Some authors evaluated the potential of OH application in the processing of whey-acerola flavored beverage, determining the frequency and electric fields intensity with effects similar to pasteurization (Cappato et al., 2018).

Research evaluating the emerging technology effect, such as HPP, Pulsed electric field and OH on the physico-chemical characteristics of whey is still scarce. The results found in the recent literature show that these technologies can affect conformation, physical stability, aggregation behavior and induce the denaturation of whey proteins,

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affecting their functional properties (Cruz et al., 2010; Krešić, Lelas, Jambrak, Herceg, & Brnčić, 2008; Pereira et al., 2016; Sharma, Oey, & Everett, 2014). Thus, the knowledge about the effects of new technologies in the whey presents great importance to the dairy sector in the development of products with sweet whey, such as dairy drinks and yogurts.

Recents studies have shown that OH has great potential for application in whey processing, with lower protein denaturation and an improvement in product's quality (Pereira, Teixeira, & Vicente, 2011). OH can influence the unfolding, denaturation, and aggregation kinetics of whey proteins (Pereira et al., 2016). According to Pereira et al. (2017), OH appears a promising technique in the development of innovative functional products, due to the effect of the electric field changes the properties of whey protein gels. However, further studies are needed to better understand the impact of OH on the physical-chemical, nutritional and sensory properties of whey.

Thus, the present work aims to evaluate the effects of conventional pasteurization and OH under different process parameters (2, 4, 5, 7, and 9 V·cm^{-1} at 60 Hz) under the same temperature profile (72–75 °C/15 s), on the physico-chemical properties (pH, rheological properties, microstructure, volatile compounds and water mobility), on nutritional properties (bioactive compounds) and sensory profile of sweet whey.

2. Material and methods

2.1. Whey processing

The OH system (Fig. 1) was located at Food Processing Laboratory of Federal Institute of Rio de Janeiro (IFRJ). It consisted of a voltage source associated with a data acquisition (volts). A polymeric jacketed tank coated with an insulating material (*Styrofoam*) was used to prevent heat loss. The electrodes were made of inert material (stainless steel) coupled to a Teflon support, together with the thermocouples and the specific thermometer for use in food. The voltage source (T) in Volts and a current meter (A) were arranged for data capture by the Data-Logger, both in the output of the variable transformer (VT) and in the system as a whole. The temperature was measured by two stainless steel Type T transmitters and data were captured using a digital multimeter. The distance between the electrodes is 11.2 cm. For better heat distribution, a glass rod was used to promote stirring in the ohmic cell.

The whey samples were prepared by reconstituting whey powder (Alibra, Minas Gerais, Brazil) in water at 11% (w/v), according to the manufacturer's instructions and following a recent study (Barukčić, Lisak-Jakopović, Herceg, Karlović, & Božanić, 2015) about the effect of ultrasound on sweet whey. The samples were subjected to OH (2, 4, 5, 7, 9 V·cm^{-1} at 60 Hz, named W_2, W_4, W_5, W_7, W_9, respectively) to 72–75 °C for 15 s (HTST – High-Temperature Short-Time), and immediately cooled in an ice bath (~0 °C). Fig. 2 shows the temperature profiles during the pasteurization of whey by OH and conventional process.

2.2. Thermal load

The thermal load was calculated using *Coxiella burnetii* as the reference microorganism, with a *z* value (temperature range required for the thermal destruction curve to cross a logarithmic cycle) of 4.34 °C (Cerf & Condron, 2006). The heating curves were constructed using the experimental data. The temperature profile was measured at intervals (5 s) during the conventional and OH until the target temperature range of 72 °C, remaining at this temperature for 15 s. The pasteurization value (F) was calculated according to Eq. (1), which can be calculated from the integration of the lethal rate as a function of time, as reported by Achir et al. (2016):

$$F = \int 10^{\frac{(T-Tref)}{z}} dt \tag{1}$$

where *T* is whey temperature, *Tref* is the reference temperature (72 °C) and *z* is the z-value of *C. burnetii*.

2.3. pH measurement and color parameters

The pH was measured using a pH meter (AKSO, AK103, São Leopoldo/RS, BR) calibrated with pH 7 and pH 4 buffer solutions, according to Amaral et al. (2018). The color measurements were performed in a Color Quest XE Spectrophotometer (Hunter Associates Laboratory, City, USA), using glass cuvettes with an optical path of 10 mm in diameter. The color parameters *a** (red-green), *b** (blue-yellow), and *L** (brightness) of the CIELAB scale were determined and were used to calculate, chroma (C*), and color variation (ΔE*) (Balthazar et al., 2015).

2.4. Bioactive compounds

The antioxidant capacity (1,1-diphenyl-2-picrylhydrazyl, DPPH radical) and ACE inhibitory activity of whey samples were evaluated in accordance with Amaral et al. (2018). For the antioxidant capacity, 0.1 mL sample and 2.85 mL of 0.06 mM DPPH, and a reaction mixture containing 0.1 mL ethanolic solution and 2.85 mL DPPH were used. The absorbance was measured at 515 nm after incubation for 60 min in the absence of light. Methyl alcohol was used as a blank for calibration of the spectrophotometer.

2.5. Particle size distribution and rheology parameters

The particle size distribution was determined by laser diffraction technique using the Mastersizer 2000 equipment (Malvern Instruments Ltd., Malvern, UK) in accordance with a recent study (Rojas, Leite, Cristianini, Alvim, & Augusto, 2016). The measurements were performed at 25 °C immediately after treatments. The mean diameter was

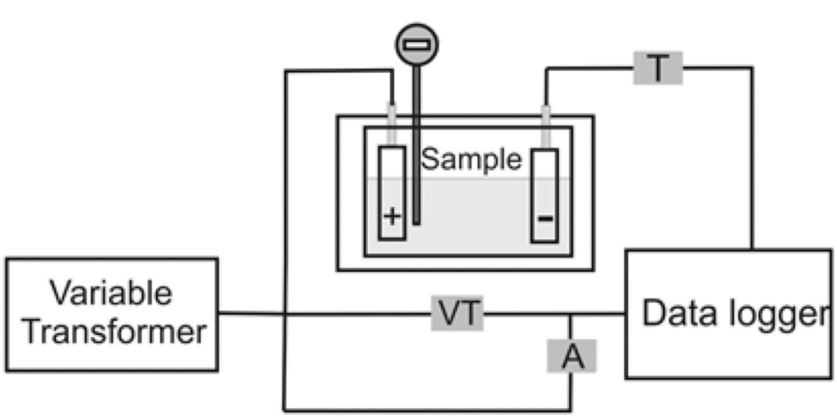

Fig. 1. Ohmic Heating diagram where (VT = voltage transducer; T = Temperature sensor; A = current transducer).