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Quality characteristics of horchata (a Spanish vegetable beverage) treated with pulsed electric fields during shelf-life

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Abstract

The application of pulsed electric fields (PEF) is one of the new non-thermal technologies being studied to evaluate their potential as alternative or complementary processes to thermal pasteurization. "Horchata de chufa" (tiger nut milk or earth almond milk) is of high nutritional quality and therefore has great potential in the food market, limited by its very short shelf-life. The present work studies whether PEF can be used to obtain a quality horchata and increase its shelf-life while maintaining its organoleptic characteristics. In order to do so we determined pH, total fat, peroxide index, thiobarbituric acid-reactive substances index, formol index, and peroxidase activity in natural (untreated) horchata and horchata subjected to various PEF treatments and studied their stability during refrigerated storage (2–4 °C). After PEF treatment, only peroxidase activity decreased significantly ($p < 0.05$). This parameter and pH varied during the shelf-life of the horchata, and a negative correlation was obtained between pH and peroxidase activity.
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Keywords: Quality; Horchata; Pulsed electric fields

1. Introduction

"Horchata de chufa" is a refreshing, non-alcoholic beverage of milky appearance, obtained from the tubers of the "chufa" (*Cyperus esculentus* L.). It is a typical product of Spain, and of great economic importance. The annual value of chufa production is close to 3 million euros (MAPA, 1997). According to the industrial production survey, 31,749 thousand litres of horchata were manufactured in 1998, representing a retail market value of some 20.1 million euros (INE, 1999). Natural horchata has a pH in the range 6.3–6.8 and is rich in starch. Consequently, it cannot be heated above 72 °C as this would cause the starch to gel and would alter the organoleptic characteristics of the product. Horchata de chufa is of high nutritional quality and therefore has great potential in the food market, limited by its very short shelf-life (Selma, Fernández, Valero, & Salmerón, 2003). The fat is rich in oleic acid (75% of total fat) and linoleic acid (9–10% of total fat), and arginine is the major amino acid, followed by glutamic acid and aspartic acid. With the exception of histidine, the essential amino acids in natural horchata de chufa are higher than the amount in the model protein proposed for adults by the FAO/OMS (Morell & Barber, 1983; Navarro et al., 1984). Treatments to improve the stability of horchata are essential for its quality, but they have been applied after significant composition changes, consisting mainly in removal of starch. This has resulted in a loss of aroma and flavour with respect to natural horchata. Consequently, there is a need to explore new technologies that are less drastic and that can preserve product quality and stabilize the product.

Undesirable quality changes may take place during some food pasteurization processes that are used to increase the shelf-life of products in order to obtain an

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acceptable commercial duration. Preservation of these characteristics is the main aim in foods described as natural, because even mild pasteurization may cause considerable losses in some characteristic properties of natural products (Lu & Whitaker, 1974). Consequently, because of consumer demand for safe but natural foods, manufacturers have begun to take an interest in finding alternatives to thermal pasteurization (Gould, 1996).

The application of pulsed electric fields (PEF) is one of the non-thermal techniques that have proved capable of increasing the shelf-life of various pumpable liquid foods.

The main aim of any preservation process is the inactivation of pathogenic or sporulated microorganisms or reduction of their growth under controlled conditions. Various studies have been published which analyze the ability of PEF to inactivate microorganisms. Sale and Hamilton (1967) indicated that, of the microorganisms studied, *Saccharomyces cerevisiae* was the most sensitive to pulse treatment. Consequently, research has been carried out with this microorganism, achieving an inactivation range between 4 and 9 log reductions, depending on the treatment conditions and substrate used (Rodrigo, Martınez, Harte, Barbosa-Cánovas, & Rodrigo, 2001). Pothakamury (1995) achieved five decimal reductions with *Lactobacillus delbrueckii*, *Bacillus subtilis* and *Staphylococcus aureus*. Inactivation studies with PEF confirm the effectiveness of this treatment and its capability as an alternative technology for food processing.

An important consideration, in any technology used for the inactivation of microorganisms, is the interpretation of survival curves. The basic models used for interpreting survival curves are based on first-order relations. Hülsheger, Potel, and Niemann (1981) were the first to propose a model that described survival curves based on the relation between the logarithm of the microbe survival and treatment time at a specific electric field intensity. Peleg (1995) proposed a model based on the Fermi equation, which related the percentage of surviving microorganisms to electric field intensity. Reina, Jin, Zhang, and Yousef (1998) found a relationship between the logarithm of the percentage of surviving microorganisms and treatment time at a determined field intensity.

Inactivation studies have concentrated both on model substrates and on real foods (orange juice, apple juice, and milk, among others).

For the study of horchata de chufa, the following parameters were selected: pH, total fat, peroxide index, thiobarbituric acid-reactive substances index (TBARS), formol index, and peroxidase activity. The possible variation of each parameter with storage was studied. As the shelf-life of natural horchata is considered to be about 48 h (Barber, 1981), we also studied storage for five days in order to establish a relationship between variation in the parameters and reduction in the quality of the horchata with time.

The aim of this work is to study whether this new, non-thermal technology (PEF) can be used to obtain a quality horchata and increase its shelf-life while maintaining its organoleptic characteristics.

2. Materials and methods

2.1. Samples

Various batches of samples were obtained directly from the manufacturer involved in the project, which supplied containers of recently made natural horchata de chufa. In total, seven samples of natural horchata were analyzed, and each was subjected to various times and electric field intensities. The analyses were performed in duplicate, and during the period of the study the samples were stored in refrigeration (2–4 °C). In parallel, for each of the PEF treatments applied, a sample was analysed, in duplicate; for this, no treatment was applied and it was designated as the blank throughout the study.

2.2. Pulsed electric field treatment system

The sample treatments were applied in a continuous PEF treatment system designed by the University of Ohio and located in the Instituto de Agroquímica y Tecnología de los Alimentos (CSIC) in Valencia. The system consisted of four treatment chambers, with a diameter of 0.23 cm and an electrode gap of 0.293 cm, connected in series and two cooling coils connected before and after each pair of chambers, immersed in a refrigerated bath in order to keep the temperature within the designated range. The temperature, wave form, voltage, and intensity in the treatment chambers were fed into a digital oscilloscope (Tektronix TDS 210, Tektronix, OR).

The flow was set at 60 ml/min and controlled by a flow pump (Cole-Parmer 75210-25, Cole-Parmer Instruments, IL). The treatment times varied between 100 and 475 μs and the electric field intensity between 20 and 35 kV/cm. The temperatures during the treatments did not exceed 35 °C.

2.3. Analytic method

2.3.1. pH

The determination of pH was based on the potentiometric measurement at 20 °C (BOE, 1988). It was determined in a Crison GLP 21 pH meter equipped with a temperature compensation sensor at 20 °C. The results were expressed to two decimal places.

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