LWT - Food Science and Technology 71 (2016) 329–338

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Optimization of time-electric field combination for PPO inactivation in sugarcane juice by ohmic heating and its shelf life assessment

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A R T I C L E I N F O

Article history:
Received 7 January 2016
Received in revised form
8 April 2016
Accepted 11 April 2016
Available online 13 April 2016

Keywords:
Sugarcane juice
PPO activity
Ohmic heating
Optimization
Leuconostoc mesenteroides

A B S T R A C T

The effect of ohmic heat (OH) treatment was measured on polyphenol oxidase (PPO) activity in sugarcane juice under different electric field strengths (24, 32 and 48 V/cm) and holding times (0.25, 0.50, 0.75, 1.0, 1.25 min) at a temperature of 80 ± 2 °C, optimized by conventional thermal (CT) treatment. The optimum temperature of PPO inactivation for CT-treatment was determined in a parallel study. The processing condition of 32 V/cm and 1 min holding time was found optimum and was analyzed for titrable acidity (TA), reducing sugars (RS), ascorbic acid (AA) and microbial load for 10 and 30 days at room and refrigeration temperatures respectively. During refrigerated storage, TA and RS remained significantly ($p < 0.01$) unchanged and the AA degradation was more pronounced at room temperature. Both treatments resulted in significant microbial reductions but growth resurfaced after 5th and 25 th day of room and refrigeration storage respectively. No yeast and mold growth was witnessed after OH-treatment. Overall, the OH-treatment was found to inhibit PPO enzyme activity in a shorter processing time than CT, while maintaining the potential quality attributes of the juice.

1. Introduction

Numerous investigations have been carried out to devise a treatment that can increase the shelf life of sugarcane juice to allow its entry into the mainstream juice processing industries. Thermal processing is the most common method studied for sugarcane juice preservation (Chauhan, Singh, Tyagi, & Balyan, 2007; Mao, Yong, & Fei, 2007; Sangeeta, Hathan, & Khatkar, 2013). Although thermal treatment is very effective for microbial and enzyme inactivation, the use of high temperatures (80–90^{O}C) is known to cause off-flavor and discoloration in the processed product (Wang & Sastry, 2002).

In the past decade, novel techniques like high pressure processing, pulsed electric field, microwave treatment, ohmic heating etc. have been studied for their application on various food products (Barba, Calabretti, d'Amore, Piccinelli, & Rastrelli, 2008; Castro, Macedo, Teixeira, & Vicente, 2004; Icier, 2005; Ohshima, Tamura, & Sato, 2007; Terefe, Yang, Knoerzer, Buckow, & Versteeg, 2010). Ohmic heating (OH) has gained wide popularity as an alternative thermal treatment as it causes volumetric heating of the sample which leads to consistent and rapid heat generation especially in liquid foods. The rate of heat generation in OH is a function of electric field strength applied across the food material (Ramaswamy, Marcotte, Sastry, & Abdelrahim, 2014). Due to short processing times, OH causes minimum discoloration and maintains the nutritive value of the food (Leizerson & Shimoni, 2005; Wang & Sastry, 2002). This feature makes it one of the most desirable treatments particularly for sugarcane juice; as it contains sensitive flavor components that are easily destroyed at longer treatment times.

Despite the problems of electrochemical degradation associated, OH has been successfully studied for its use in preheating, blanching, and extraction (Lakkakula, Lima, & Walker, 2004; Leizerson & Shimoni, 2005; Lima & Sastry, 1999). The major focus of most studies has been on commercial products like strawberry pulp, grape juice etc (Castro et al., 2004; Icier, Yildiz, & Baysal, 2008).

Sugarcane juice is a proven health promoting food which is primarily known to fight cancer and prevent kidney problems (Singh, Gaikwad, & More, 2014). However, PPO browning and microbial spoilage have limited the storage of fresh juice to just a few hours. Over the years, sugarcane juice has been investigated for its shelf life by blending it with curd, lime juice and other preservatives (Khare, Lal, Singh, & Singh, 2012; Sneh, Chaturvedi, Kuna,

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http://dx.doi.org/10.1016/j.lwt.2016.04.015
0023-6438/

Table 1
Processing times for different combinations of CT and OH-treatments.

Treatment type	EFS	Holding temp. (°C)	Heating time (min)	Holding time (min)	Total processing time (min)
CT	–	60 ± 1	3.80	5,10,15,20	8.8, 13.8, 13.8, 18.8, 23.8
	–	70 ± 1	4.90	5,10,15,20	9.9, 14.9, 19.9, 24.9
	–	80 ± 1	6.00	5,10,15,20	11.0, 16.0, 21.0, 26.0
	–	90 ± 1	7.00	5,10,15,20	12.0, 17.0, 22.0, 27.0
OH	24	80 ± 2	3.25	0.25, 0.5, 0.75, 1.0, 1.25	3.5, 3.75, 4.0, 4.25, 4.5
	32	80 ± 2	1.50	0.25, 0.5, 0.75, 1.0, 1.25	1.75, 2.0, 2.25, 2.5, 2.75
	48	80 ± 2	0.45	0.25, 0.5, 0.75, 1.0, 1.25	0.7, 0.95, 1.2, 1.45, 1.7

& Dhanlakshmi, 2012), however, limited literature is available on the application of a novel technique such as OH to increase the shelf life of the product. Although the rate of heating under OH and conventional thermal (CT) are different, the present study was conducted to explore the option of an alternative treatment for sugarcane juice processing. Therefore, the objectives of this investigation were to determine the influence of OH on PPO inactivation in sugarcane juice under a wide range of electric field strengths and compare the observations with those of the CT treatment. Shelf-life studies were also conducted for the optimized treatments and quality attributes like titrable acidity (TA), ascorbic acid (AA), reducing sugars (RS) and microbial count was studied.

2. Materials and methods

2.1. Sample preparation

Fully mature sugarcane stems of '*Pharma*' variety were procured from the farms in Sonitpur, Assam, India. The stems were peeled, manually cut and crushed in 'Usha' Food Processor (make: FP2663, India) to yield the juice. The juice was subsequently filtered through four-folds of muslincloth to obtain a clear filtrate which was used throughout the study. Fresh juice was extracted prior to each treatment.

2.2. CT-treatment

The CT-treatment was carried out to establish effective comparison between the OH-& CT-treatment results. A volume of 50 ml of juice samples was heated at sixteen different processing combinations of temperature (60, 70, 80 and 90 °C) and holding time (5, 10, 15 and 20 min) in a lab scale water bath (BW-20G,JEIOTech, Korea). The heating, holding and total processing times are shown in Table 1.

2.3. OH- treatment

The OH-treatment was applied in a lab scale ohmic heater whose setup (Fig. 1) includes one movable and one stationary stainless steel electrode (grade 316) of 1.5 mm thickness and 25 mm diameter enclosed in a hollow cylindrical casing of Teflon with an outer and inner diameter of 50 mm and 25.5 mm respectively. An opening of 5 mm diameter was made on the surface, at a distance of 50 mm from each electrode for the feed and a teflon-coated thermocouple was inserted to measure the temperature at the centre of the cylinder.

A power supply of 240 V and 50 Hz frequency was used to carry out the experiments. The OH-treatment was employed at three different electric field strengths (24, 32 and 48 V/cm) for five holding times (0.25, 0.50, 0.75, 1.0, 1.25 min). The electric field strengths were maintained by adjusting the distance between the two electrodes. Thus, the volumetric capacity of the equipment varied from 50 ml at 24 V/cm, 35 ml at 32 V/cm and 25 ml at 48 V/cm. A digital temperature controller-cum-indicator was used to maintain the temperature of the juice at 80 ± 2 °C (optimized temperature of CT-treatment, discussed in section 3.3). The heat-up time to reach 80 ± 2 °C at different electric field strengths is shown in Table 1. The samples were held at 80 ± 2 °C for the specified holding times.

After both the treatments, the samples were immediately cooled and analyzed for their residual PPO activity.

2.4. Polyphenol oxidase (PPO) enzyme assay

The assay of the enzyme was carried out as described by Ozoglu and Bayindirli (2002). One ml of 0.2 mol/L Catechol solution was added to mixture of 0.5 ml of sugarcane juice and 2 ml of phosphate buffer (pH 6.5). The absorbance was measured at 420 nm at every 1 min interval. The enzyme activity was estimated from the linear

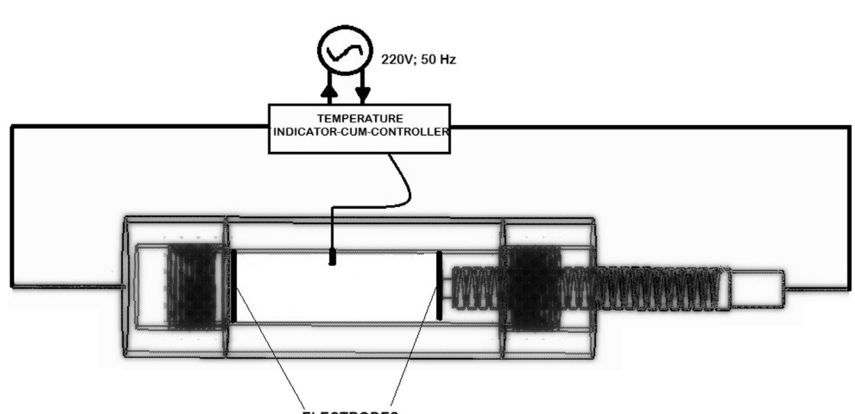

Fig. 1. Schematic Diagram of Ohmic heating set up.