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ScienceDirect
Journal of Food Engineering 83 (2007) 41–46
JOURNAL OF FOOD ENGINEERING
www.elsevier.com/locate/jfoodeng

Thermal and pulsed electric fields pasteurization of apple juice: Effects on physicochemical properties and flavour compounds

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Received 6 September 2006; received in revised form 14 December 2006; accepted 15 December 2006
Available online 11 January 2007

Abstract

Apple juice, extracted from golden delicious fruits, was pasteurized using a pulsed electric field (PEF) treatment and compared with a conventional high temperature-short time (HTST) method. The PEF treatment was carried out using a PEF laboratory unit, set with a bipolar pulse (4 μs wide), an intensity of 35 kV/cm, and a frequency of 1200 pulses per second (pps). The thermal pasteurization was performed at 90 °C for 30 s with an adapted laboratory set-up. Effects of variables of both treatments on pH, total acidity, phenolics content, and volatile compounds were investigated. While minimal variability was observed in pH and no significant changes were detected in acidity, phenolics content and volatile compounds concentration showed statistical significant differences between treatments. In general, these measured variables were less affected by the PEF treatment than by the thermal pasteurization.

Keywords: Apple juice; Thermal pasteurization; High voltage pulsed electric fields (PEF); High temperature-short time (HTST) pasteurization; Sensory attributes

1. Introduction

Apple juice has been traditionally pasteurized by thermal means. Both batch and continuous methods are used in apple juice pasteurization and the treatment may be carried out before or after packing the product in the container. In batch pasteurization, individual volumes are treated in jacketed stainless steel vessels. The jacket may be used both for heating (with steam or hot water) and cooling (with chilled water or brine). Continuous pasteurization may be carried out by passing the juice through plate heat exchangers, which usually comprise the stages of pre-heating, heating, holding and cooling. Currently, high temperature-short time (HTST) pasteurization is a commonly used method for heat treatment of apple juice. In HTST pasteurization, the temperature used is 76.6–87.7 °C for a holding time between 25 and 30 s (Moyer & Aitken, 1980).

Thermal pasteurization is quite efficient in preventing microbial spoilage of apple juice but the applied heat may also cause undesirable biochemical and nutritious changes which may affect overall quality of the final product. Alternative methods of pasteurization that do not include direct heat have been investigated in order to obtain a product safe for consumption, but with sensory attributes similar to the untreated juice. High voltage pulsed electric fields (PEF) treatment is a promising non-thermal processing method that may radically change liquid food preservation technology. Treating liquid foods with PEF may inactivate micro-organisms and enzymes with only a small increase in temperature, simultaneously providing consumers with safe, nutritious, and fresh-like

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doi:10.1016/j.jfoodeng.2006.12.011

quality foods. PEF treatment is conducted at ambient temperature for a short time (in microseconds), and energy lost due to heating of foods is minimized (Jeyamkondan, Jayas, & Holley, 1999).

In terms of microbial safety and energy efficiency, a study of PEF inactivation demonstrated that, for achieving a seven log reduction in survivability of *Saccharomyces cerevisiae* in apple juice, PEF utilized less than 10% of the electric energy for heat treatment (Qin, Zhang, Barbosa-Cánovas, Swanson, & Pedrow, 1994). It has also been reported (Mittal, 1998) that a PEF low energy pulser with an instant-charge-reversal pulse waveform was successfully used in apple cider treatment. The consumed energy was as low as 5.76 J/ml at 20 °C, compared with the 50 kJ/kg normally required in conventional thermal processing. Microbial inactivation, coupled with quality retention, has also been reported for apple juice pasteurization using non-thermal methods of preservation (Ortega-Rivas, Zárate-Rodríguez, & Barbosa-Cánovas, 1998). A comparison of ultrafiltration (UF) and PEF in apple juice pasteurization reported six log reductions in survivability of total aerobic micro-organisms using the indigenous flora of the juice (Ortega-Rivas et al., 1998). In terms of quality aspects, soluble solids, pH and acidity were reported practically impaired by both techniques. Colour, however, suffered changes such as browning for UF and fading for PEF (Ortega-Rivas et al., 1998; Zárate-Rodríguez, Ortega-Rivas, & Barbosa-Cánovas, 2000).

Flavour components in apple juice are numerous, and flavour identification is considered quite complex due to the aromatic nature of apples. Eight odour-active volatiles have been, however, identified as the most important contributors for the aroma–flavour authenticity of apple juice (Cunningham, Acree, Barnard, Butts, & Braell, 1986). Apparently, there are not reported studies of PEF effects on volatile compounds in apple juice. Several reports have appeared for orange juice (Jia, Zhang, & Min, 1999; Yeom, Streaker, Zhang, & Min, 2000) focusing on effects of PEF on quality aspects. The PEF-treated juice was compared with juice pasteurized by heat at 94.6 °C for 30 s. The juice treated by PEF retained greater amounts of vitamin C and some representative flavour compounds, than the juice pasteurized by heat during storage at 4 °C. In terms of specific flavour compounds, it was found that 40% of decanal was lost by heat treatment at 90 °C for 3 min while no loss was observed by PEF treatment at 30 kV/cm, either at 240 or 480 μs (Jia et al., 1999). Octanal showed a loss of 9.9% for the heat treatment and 0% for any of the two PEF treatments. Some compounds suffered losses for the PEF treatments, but always in less proportion than the heat pasteurized juice. For example, 5.1% and 9.7% of ethyl butyrate were lost for the 240 μs and 480 μs treatments, respectively, but 22.4% was lost in the thermal process (Jia et al., 1999).

As discussed above, PEF has been challenged against many spoiling micro-organisms in apple juice, with encouraging results. Also, pertaining quality, there are studies looking at effects on physicochemical properties and some sensory attributes, with results also being promising. For example, Evrendilek et al. (2000) reported no apparent changes in physical and chemical properties directly caused by PEF treatment in apple juice and cider, while Barbosa-Canovas, Pothakamury, Palou, and Swanson (1998) found that pH and vitamin C concentration were not significantly affected by PEF treatment of fresh apple juice and apple juice reconstituted from concentrate. There is, however, a dearth of information in the literature related to actual effects of PEF on composition of volatile chemical compounds responsible for odour and flavour of apple juice. There are neither many direct comparisons of PEF and HTST treatments, in terms of quality attributes in general. This paper presents an investigation of a direct comparison of PEF and HTST in pasteurization of apple juice, focused on retention of volatile compounds, which have been identified as responsible for its characteristic aroma and tasteful flavour.

2. Materials and methods

Freshly squeezed apple juice, from golden delicious apple variety, was extracted with a domestic juice extractor. The juice was pre-filtered across a bag filter and stored at 4 °C prior to treatment.

For conventional heat treatment, an experimental set-up was constructed (Fig. 1). As can be observed, it consisted of sanitary containers to hold heating and cooling fluids, coils for juice passage, a centrifugal sanitary pump to circulate the juice, and thermocouples to record the temperature. A pasteurization temperature of 90 °C was tested for a holding time of 30 s, which was virtually the maximum range suggested in the literature (Moyer & Aitken, 1980). Also, it was sufficient to achieve pasteurization conditions using *Lactobacillus brevis* and *S. cerevisiae*, common spoilage micro-organisms in apple juice, as contaminating species. As shown in Fig. 2, inoculates of *L. brevis* and *S. cerevisiae*, expressed in colony forming units per millilitre (cfu/ml) were properly reduced.

A high voltage pulsed electric field unit, designed and constructed at Ohio State University (Columbus, OH, USA) was used for the PEF treatment. As shown in Fig. 3, this test apparatus consists of a high voltage power

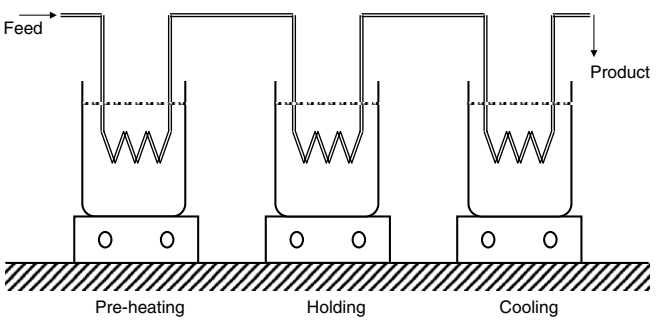

Fig. 1. Experimental set-up used for heat pasteurization of apple juice.