COMPARISON OF THERMAL PROCESSING AND PULSED ELECTRIC FIELDS TREATMENT IN PASTEURIZATION OF APPLE JUICE

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Abstract: Apple juice is a popular beverage worldwide, which is perceived as a wholesome and nutritious product. Overall quality of apple juice is an important factor to consider in processing, since some attributes, such as aroma, colour and flavour, are well appreciated by the final consumer, and are associated with freshness and authenticity. Non-thermal processing was tested in apple juice pasteurization in order to verify its feasibility in microbial inactivation, as well as its possibility of rendering a product impaired in terms of some sensory attributes. The non-thermal technique of high voltage pulsed electric fields (PEF) treatment, was compared with conventional high temperature-short time (HTST) pasteurization. Effects of process variables, such as voltage intensity and frequency for the PEF treatment, as well as temperature and time for the HTST pasteurization were investigated over inactivation of *Escherichia coli* and changes of pH and colour. Both techniques achieved more than five log reductions in microbial inactivation, normally considered the standard for fruit juices pasteurization. Apparently, PEF preserved better the pH than HTST as the thermal treatment showed an increase in this physicochemical property. Some variability was observed in terms of colour for all the treatments.

Keywords: apple juice; heat pasteurization; non-thermal pasteurization; high voltage pulsed electric fields.

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INTRODUCTION

Apple juice has been traditionally pasteurized by thermal means using continuous pasteurization, which may be carried out by passage through plate heat exchangers, and by tunnel pasteurizers. Currently, HTST pasteurization is the mode commonly used 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 and Aitken, 1980). Thermal processing inactivates spoiling micro-organisms efficiently, but may also degrade taste, colour, flavour and nutritional quality of foods (Qin *et al.*, 1995a).

PEF treatment is a promising non-thermal processing method that may radically change liquid food preservation technology. PEF inactivates micro-organisms and enzymes with only a small increase in temperature, simultaneously providing consumers with safe, nutritious and fresh-like quality foods. Several studies of PEF treatment of apple juice have appeared in the literature (Qin *et al.*, 1994, 1995b; Mittal, 1998; Ortega-Rivas *et al.*, 1998; Evrendilek *et al.*, 1999; Zárate-Rodríguez *et al.*, 2000).

Although fundamental research on PEF is advancing while its commercial application has been reported feasible (Braakman, 2003), there are only few comparative studies of PEF against conventional thermal treatment in the literature (e.g., Wouters *et al.*, 1999). More comparative studies are needed in order to determine whether PEF treatment may produce apple juice safe and natural, under the same conditions of the traditional, thermal pasteurization method. This paper presents the results of an investigation aimed at comparing aspects of microbial safety and quality assurance of apple juice treated by HTST and PEF.

MATERIALS AND METHODS

Freshly squeezed apple juice of the Gala variety was obtained using a domestic juice extractor. The juice was stored for 24 h at 4°C, then pre-filtered across a bag filter

(1 mm pore size), and finally processed by the pasteurization methods previously described. *Escherichia coli* 8739 was grown in tryphtic soy broth (TSB) and incubated at 35°C until reaching an absorbance of 1.8 at 600 nm, corresponding to an end logarithmic growth phase with a viable count of 80×10^7 colony forming units per millilitre ($cfuml^{-1}$). *E. coli* was chosen as a main indicator for microbial inactivation as outbreaks of this bacterium were observed in the USA in 1996 (Heinz *et al.*, 2003). The grown micro-organism was suspended in the apple juice 30 min before treatment. The viability of *E. coli* before and after testing by HTST and PEF was assayed by counting colony forming units on violent red brilliant agar (VRBA). One microlitre of the treated juice was used, serially diluted with 0.1% sterile peptone solution, and 100 μl of dilution plated on VRBA at 35°C for 48 h. The treated fluids were diluted to obtain colony forming units between 20 and 200. The mean was calculated from four plates.

For conventional heat treatment, an experimental set-up was constructed. 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. Pasteurization temperatures of 73, 80 and 83°C were tested at a holding time of 27 s.

A Bench Scale Pulsed Electric Field Processor Model OSU 4-H (Ohio State University, Columbus, OH, USA) was used for the PEF treatment. Its operating details are described in Table 1 and a schematic diagram illustrated in Figure 1. Electric field strengths of 12, 24 and 36 kV cm^{-1} and replication rates of 400, 600 and 800 pulses per second (pps) were studied.

The effects of all the variables mentioned above on the pasteurization methods were evaluated for effects on pH and colour of the pasteurized juice. To measure pH an Orion Benchtop pH-meter Model 370 (Orion Research Inc., Boston, MA, USA) was used. Colour components *L* (brightness/whiteness), *a* (redness) and *b* (yellowness), based on the Hunter system, were measured with a Hunter Lab Ultra Scan XE (Hunter Laboratory, Reston, VA, USA) colorimeter.

To analyse the results multiple linear regression was used for each effect studied based on correlation values and model significant levels. All means were subjected to Student's *t*-test to verify significant differences between the quality attributes investigated. Significance of differences was defined at $P < 0.05$. The actual calculations were carried out utilizing the Statistica package (Statsoft Inc., Tulsa OK, USA).

Table 1. Characteristics of PEF unit (OSU 4-H).

Description	Operating conditions
A *Pulse generator module*	
Operating voltage	0–12 kV
Peak current	0–100 A
Polarity	Bipolar or unipolar
Wave shape	Square wave
Pulse duration	1–10 μs
Repetition rate	Single shot to 2000 pps*
B *Treatment chamber module*	
Number of chambers	2–8
Cooling capacity	10°C per chamber pair
System flow rate	0.5–8 ml s^{-1}
Number of pulses per chamber	9 (under 1500 pps unipolar output with 2 ml s^{-1} flow rate)
Total treatment time	190 μs (using eight chambers, 1500 pps, 2 ml s^{-1} flow rate, and 2.5 μs pulse duration)
C *Fluid handling module*	
Batch size	60 ml in syringes
Type of fluid	Liquid, viscosity <0.2 Pas
Back pressure	1.034 bar
Syringe pump for automated operation	

*Pulses per second.

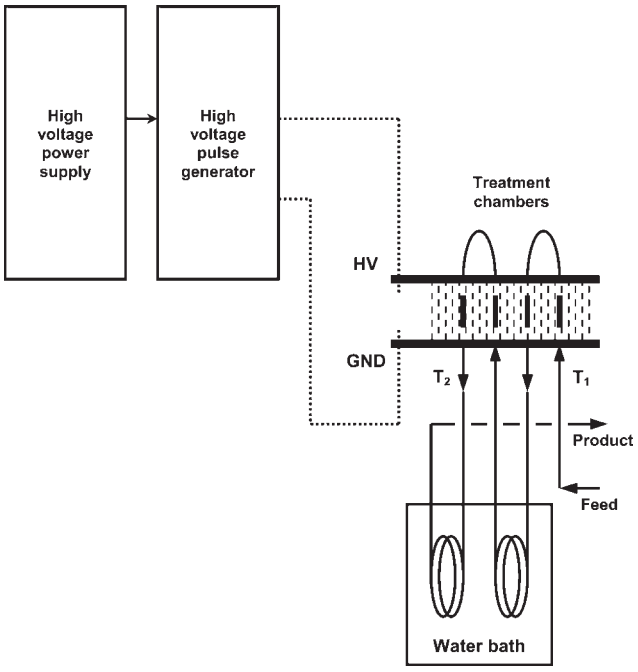

Figure 1. Diagram of pulsed electric field treatment operation.

RESULTS AND DISCUSSION

As mentioned above, multiple linear regression was used to fit the experimental data. For the case of HTST testing, regression equations could be fitted to describe properly an inactivation of *E. coli* and an increase in pH, both directly related to temperature. Pertaining colour, no regression expression could be fitted at any significant degree of correlation.

High correlation coefficients were found for the regression models fitted, having values of 0.9725 for the survival ratio and 0.9909 for the pH effect. In terms of pH, an increase directly related with temperature was observed (Figure 2), which could be explained in terms of the evaporative effect of organic acids. This variation of pH with temperature could have an effect in shelf life, since higher pH could raise the possibility of yeasts growth or enzyme activity.

As previously mentioned, no regression expression could be fitted at any significant degree of correlation for colour change. Although colour differences were not highly significant, the graphical variation of colour parameters *L*, *a* and *b* as a function of temperature, as given in Figure 3, showed a similar trend somewhat. The parameter *L* represents brightness/whiteness of a given sample, so it can