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Quality degradation kinetics of pasteurised and high pressure processed fresh Navel orange juice: Nutritional parameters and shelf life

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Abstract

A kinetic study of post processing quality loss was conducted after high pressure processing (600 MPa, 40 °C, 4 min) or thermal pasteurisation (80 °C, 60 s) of fresh Navel orange juice. Selection of processing conditions was mainly based on pectin methylesterase inactivation. Ascorbic acid loss, colour, viscosity and sensory characteristics were measured during storage at different isothermal conditions (0–30 °C). Increased shelf life (based on ascorbic acid retention) was achieved for high pressurised compared to thermally pasteurised juice, ranging from 49% (storage at 15 °C) to 112% (storage at 0 °C). Activation energy values for ascorbic acid loss were 68.5 and 53.1 kJ/mol, respectively, for high pressurised and thermally treated juice. High pressure processing resulted in better retention of flavour of untreated juice and superior sensory characteristics compared to thermal pasteurisation. Colour change was linearly correlated to ascorbic acid loss for both types of processing. Slightly higher apparent viscosity values were determined for high pressurised juice.

Keywords: Kinetics; Shelf life; Ascorbic acid; High pressure; Pasteurisation; Orange juice

Industrial relevance: Application of high hydrostatic pressure on orange juice industry. Fresh orange juice is a product of high commercial and nutritional value due to its rich vitamin C content and its desired sensory characteristics. High Hydrostatic Pressure (HHP) is an alternative non-thermal technology that has been proposed for application on orange juice. Such a treatment denaturates enzymes and eliminates microorganisms responsible for spoilage of orange juice without detrimental effects on the sensory and nutritional quality of juice. The effect of HHP on the stability of fresh orange juice has been studied by different research groups, while orange juices processed with the new technology have already been commercially available in Japan, U.S.A., Mexico and Europe. However, a systematic kinetic approach of the effect of HHP on different quality indexes (not only microbial spoilage) immediately after processing, as well as during a long term storage of the processed orange juice is needed, in order to achieve an optimal process design and a successful application of the new technology in orange juice industry. Such kinetic data for parameters related to the quality and nutritional value of fresh orange juice were gathered in the present work providing therefore industry with useful information for the HHP stabilization of orange juice and the production of a high quality product. Due to the great benefits of HHP compared to the conventional pasteurization that emerged from this work regarding the quality, shelf life and nutritional characteristics of fresh orange juice, HHP technology is an advantageous alternative process for high valued products like orange juice.

1. Introduction

High hydrostatic pressure (HHP) processing has been introduced as an alternative non-thermal technology for preservation of orange juice. A major problem associated with orange juice quality deterioration during storage is cloud loss accompanied by gelation of juice concentrates. This action has been primarily attributed to the activity of pectin methylesterase (PME) (Cameron, Baker, & Grohmann, 1997; 1998; Versteeg, Rombouts, Spaansen, & Pilnik, 1980), the inactivation of which is generally used to determine the intensity of thermal processing during

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commercial pasteurisation (Snir, Koehler, Sims, & Wicker, 1996; Versteeg et al., 1980). Pasteurisation conditions used to inactivate the most heat resistant PME iso-enzyme (90 °C for 1 min) reduce “freshness”, affecting sensory and nutritional characteristics of orange juice (Manso, Oliveira, Oliveira, & Frias, 2001; Yeom, Streaker, Zhang, & Min, 2000). HHP achieves inactivation of microorganisms (Linton, McClements, & Patterson, 1999; Parish, 1998a; Zook, Parish, Braddock, & Balaban, 1999), inactivation of orange PME (Basak, Ramaswamy, & Simpson, 2001; Nienaber & Shellhammer, 2001a; Parish, 1998a; Van den Broeck, Ludikhuyze, Van Loey, & Hendrickx, 2000) and denaturation of several other enzymes (Cano, Hernández, & De Ancos, 1997; Weemaes, Ludikhuyze, Van den Broeck, & Hendrickx, 1999), while minimally affecting quality and organoleptic characteristics (Fernández-García, Butz, Bognar, & Tauscher, 2001; Nienaber & Shellhammer, 2001b). PME exhibits greater heat and pressure resistance compared to that of common spoilage microorganisms of orange juice and thus can be used as processing index for both HHP and thermal process (Goodner, Braddock, & Parish, 1998; Versteeg et al., 1980).

The effect of HHP on post processing quality loss of orange juice is an important issue for study. During storage, orange juice undergoes a number of deteriorative reactions resulting in quality degradation of the product. Among them, ascorbic acid is degraded, following two consecutive or parallel pathways, aerobically and anaerobically, at rates depending on storage conditions, packaging and type of processing (Kennedy, Rivera, Lloyd, Warner, & Jumel, 1992; Sadler, Parish, Van Clief, & Davis, 1997; Tawfik & Huyghebaert, 1998). Remaining ascorbic acid constitutes an important quality indicator often defining the shelf life of the product (Lee & Chen, 1998; Lee & Coates, 1999). Loss of nutrients other than ascorbic acid, cloud loss, microbial spoilage, development of off-flavour, changes in colour, texture and appearance are other phenomena that influence the overall quality of orange juice (Goyle & Ojha, 1998; Roig, Bello, Rivera, & Kennedy, 1999).

Application of HHP can lead to an extended shelf life of orange juice compared to that of untreated juice with minimal product quality loss and a good retention of fresh-like flavour (Donsi, Ferrari, & Di Matteo, 1996; Nienaber & Shellhammer, 2001b). Although several studies reported retention of the overall quality of high pressure processed orange juice and increase of its shelf life compared to that of untreated juice, few works compare the effect of an alternative HHP process with that of a conventional heat pasteurisation on orange juice quality parameters during storage, studying only specific quality indicators, e.g. sensory characteristics or microbial growth (Parish, 1998b). A comparative study of HHP and thermal pasteurisation concerning their effect on a number of qualitative characteristics during storage has been reported for reconstituted from frozen concentrate orange juice (Polydera, Stoforos, & Taoukis, 2003), which is the most common type of orange juice produced worldwide. However, the increasing consumers’ demand for minimally processed products and the main advantage of HHP to retain the sensory and quality characteristics of the processed product make fresh orange juice the most likely type of juice for HHP application.

The objective of this work was to comparatively evaluate the effect of conventional thermal pasteurisation and alternative HHP processing on post processing quality loss of fresh Navel orange juice. Selection of process conditions was based on PME inactivation kinetics. Additional criteria considered were sensory quality and microbial stability of orange juice. The shelf life of juices was determined at different storage temperatures within the broad range of 0–30 °C. Determination of shelf life was mainly based on ascorbic acid loss kinetics, while a variety of other quality parameters such as sensory characteristics, colour and viscosity were also investigated.

2. Materials and methods

2.1. Juice samples

Orange juice of greek Navel variety (*Citrus sinensis*), from a Food Manufacturing Coalition (FMC) production line of a commercial juice plant in Southern Greece was obtained. No thermal treatment was applied. The juice was immediately frozen in a forced circulation freezer (MDF-U442, SANYO Electric, Japan) and kept at −40 °C until use.

2.2. High pressure processing

High pressure treatments were achieved using a laboratory pilot scale HHP equipment with a maximum operating pressure of 1000 MPa (Food Pressure Unit FPU 1.01, Resato International, Roden, Holland) consisting of an operation high pressure unit with a pressure intensifier, a high pressure vessel of 1.5 L in volume and a multivessel system consisting of six vessels of 45 mL capacity each. All high pressure vessels were surrounded by a liquid circulating jacket connected to a heating–cooling system. The pressure transmitting fluid used was polyglycol ISO viscosity class VG 15 (Resato International).

For the HHP experiments, polypropylene bottles of 150 mL capacity with screw-cup closures were used. Fifty bottles were filled with orange juice and placed into the large vessel for processing. The desired value of pressure (600 MPa) was set and after pressure build-up (about 1 min), the pressure vessel was isolated. This point defined the time zero of the process. Pressure was released after a preset time interval (4 min) by opening the pressure valve. The initial temperature increase during pressure build-up (about 3 °C/100 MPa) was taken into consideration in order to achieve an average operating temperature of 40 °C during pressurisation.