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High Pressure Carbon Dioxide pasteurization of coconut water: A sport drink with high nutritional and sensory quality

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ABSTRACT

High Pressure Carbon Dioxide (HPCD) treatment was applied to the pasteurization of coconut water in order to guarantee both its microbial stability and preserve its nutritional and sensory attributes. It was demonstrated that 120 bar, 40 °C, 30 min were the optimal process conditions to induce a 5 Log(CFU/ml) reduction of mesophilic microorganisms, lactic acid bacteria, yeasts and molds and a 7 Log reduction of the total coliforms. The effect of HPCD on the quality traits of coconut water were investigated by means of physical–chemical and sensory analyses and compared to the Heat Pasteurized (HP, 90 °C, 1 min) and Fresh Untreated (FU) product. No differences in the basic chemical composition, vitamins and amino acids, were detected between HPCD and FU products. However, differences in the volatile compounds present in the three products were clearly distinguishable; HPCD resulted in a reduction of most of the volatile fractions while HP induced the formation of compounds with a toasted and malty aroma. Nevertheless, few sensory differences were perceived between the FU and the HPCD coconut water, and both were clearly differentiated from the HP product.

1. Introduction

The hydration and absorption of liquids with a high content of mineral salts, vitamins, sugars and nutritional substances are fundamental for a correct diet of active people. Decades of research clearly demonstrate the benefits derived from the consumption of drinks during and after physical activity (Sawka et al., 2007). Coconut water, the clear liquid inside young green coconuts, is becoming more and more popular among the athletes as a healthy drink rich in vitamin C, magnesium, calcium, potassium, vitamin B, arginine, alanine, lysine, glutamic acid, enzymes with anti-inflammatory properties, minerals and antioxidants (Reddy, 1995). Its claims as a natural alternative in the sports drink market are supported by its low calorie content (about 17.4 kcal per 100 g), and by its delicate aroma, taste, nutritional and functional characteristics (FAO, 2000).

Currently, coconut water is processed by heat treatments, which destroy the natural microbial flora occurring in the product, prolonging its shelf life for 2–3 months (Reddy, 1995). The high process temperatures of heat pasteurization (HP) grossly alter the product's sensory quality and change its nutritional contents. Different preservation techniques like filtration, increasing the sugar and total solid content, pH adjustment, ultrasonic treatments, concentration by reverse osmosis, spray drying, the addition of preservatives, etc., have been investigated either alone or in various combinations (Reddy, 1995; Bergonia et al., 1982; Magda, 1992; Reddy et al., 2005). High Pressure Carbon Dioxide (HPCD) is an emerging non-thermal treatment processes, in addition to Pulsed Electric Fields (Zhao et al. 2012) and High Hydrostatic Pressures (Rendueles et al., 2011). Since the 1980s, HPCD has been increasingly considered as a technique able to induce the inactivation of the natural microbial flora and pathogens occurring in solid and liquid matrices (Arreola et al., 1991; Zhou et al., 2009; Spilimbergo and Ciola, 2010a; Ferrentino and Spilimbergo, 2011). The CO_2 used in this process is relatively inert, inexpensive, non-toxic, non-flammable, recyclable and readily available in high purity, and leaves no residues when removed after the treatment process. Furthermore, it is considered a Generally Recognized as Safe (GRAS) substance, meaning it can be used safely on food products.

Several studies have addressed the effect of HPCD treatment on the physical–chemical parameters of fruit juices and beverages (Gui et al., 2005; Ferrentino et al., 2009). Zhou et al. (2009) treated carrot juice with HPCD showing that the browning degree and pH of the treated juice decreased, the cloud and the titratable acidity

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increased, polyphenol oxidase was inactivated, and that the soluble solids and carotenoids were stable. Gasperi et al. (2009) also tested the efficiency of the process on fresh apple juice. They confirmed that CO_2 was able to inactivate microorganisms naturally present in the juice with a 10 min treatment at 10 MPa and 36 °C. The process did not change the composition of the juice in terms of sugars, amino acid content acidity, and polyphenol concentration. However, analysis performed with Solid Phase Microextraction Gas Chromatography – Mass Spectrometry (SPME GC–MS) and Proton Transfer Reaction – Mass Spectrometry (PTR-MS) indicated that the treatment induced a reduction in the concentration of many volatile compounds (esters and aldehydes) responsible for the observed changes in the odor and flavor of the treated juice. Damar et al. (2009) applied the HPCD process to coconut water for the first time, using a continuous system with the objective to evaluate the microbial inactivation, physical–chemical characteristics, and the consumer acceptability of the coconut water after the treatment. In this study, the experiments were carried out on an acidified (with the addition of malic acid to lower the pH to 4.20), sweetened (with the addition of a chemically modified form of sucrose in concentration of 0.7% *w*/*w*, °Brix equal to 6.0) and carbonated (with the addition of CO_2 at 4 °C and 0.18 MPa) coconut water. The results were promising, with a decrease of total aerobic bacteria by more than 5 Log(CFU/ml), (logarithm of colony forming unit per ml of sample) and with a good product likeability, despite the pH decrease and the sugar increase.

In this context, the present study aimed to investigate the possibility of applying HPCD treatment to the pasteurization of natural coconut water in order to guarantee both its microbial stability and the retention of its quality attributes, without the addition of acidifiers or sweeteners. The feasibility of the process was determined by the inactivation of the natural microbial flora (mesophilic microorganisms, lactic acid bacteria, total coliforms, yeasts and molds) as a function of pressure, temperature and time.

The impact of the process on the quality traits of the coconut water was also verified through a deep physical–chemical and nutritional characterization (pH, soluble solids, mineral salts, sugars, vitamins, amino acids, and volatile compounds) in order to investigate the effects of the treatment on the composition, paying particular attention to the compounds with nutritional importance or sensory impact. Despite sensory quality is one of the key factors for consumer acceptance, only a few papers considered this aspect for coconut water (Assa et al., 2013). These studies investigated the acceptability of coconut water treated with different processes, but basic sensory analysis principles were not rigorously respected (Damar et al., 2009; Silva do Amaral et al., 2012). In the present study, a descriptive sensory analysis performed by a trained panel was carried out with the aim to verify whether HPCD treatment induced potentially perceptible sensory modifications, compared to fresh untreated (FU) and heat pasteurized (HP) coconut water.

2. Materials and methods

2.1. Coconut water

2.1.1. Extraction and filtration

Seventy young green coconuts (*Cocos nucifera cv Nam Hom*) from Thailand were bought and sent to Trento where they were aseptically opened, the water extracted and accumulated in a 20 l plastic pail and placed in an ice bath. A flow of inert gas (Argon) was used to create an oxygen free atmosphere above the collected coconut water to avoid any possible oxidation. After the extraction process, coconut water was homogenized, portioned in sterilized glass jars of 200 or 400 ml and immediately frozen at −20 °C to prevent any microbial or enzymatic activity. All samples for further trials were prepared by thawing the coconut water glass jars at 4 °C for 12 h.

2.1.2. Coconut water contamination for HPCD and HP

The initial microbial load of coconut water was measured after the extraction process. The product showed 4 Log (CFU/ml) of mesophilic microorganisms and 2 Log (CFU/ml) of lactic acid bacteria, total coliforms and yeasts and molds, by standard plate count. To evaluate the effect of the processes, the coconut water was aged at 30 °C for 18 h to increase the initial microbial load. The resulting microbial load was about 8.5 Log (CFU/ml) of mesophilic microorganisms, lactic acid bacteria, and total coliforms and about 6 Log (CFU/ml) of yeasts and molds.

2.2. Set up of the optimal stabilization conditions

2.2.1. HPCD treatment

HPCD treatments were carried out in a multi-batch apparatus. The system consisted of 10 identical reactors with an internal volume of 15 ml connected in parallel, so that each experimental run provided a set of experimental data taken in identical process conditions but at different treatment times. Each reactor was connected to an on–off valve that could be used to depressurize it independently from the others. The 10 reactors were submerged in a single temperature-controlled water bath. Liquid CO_2 (Messer, Carbon dioxide 4.0, purity 99.990%) was fed into the reactors by a volumetric pump (Lewa, mod. LCD1/M910s) that increased the pressure to the desired processing levels, at a rate of about 6 MPa/min. The apparatus was provided with a transducer (Hendress + Houser GmbH, Maulburg, Germany) to control the pressure values while one cover lid of the 10 reactors was equipped with a fixed thermocouple (Pt 100′Ω) to measure the product temperature. At the end of the process, two micrometric valves and one on–off valve were used to depressurize and release CO_2 from the apparatus over approximately 1 min. The processed samples were collected in sterile containers and cooled down immediately at 4 °C until further use.

The operating parameters (temperature, pressure and time) were continuously recorded by a real time data acquisition system (National Instruments, field point FP-1000 RS 232/RS 485) and monitored by a custom program (LabView™ 5.0). The process conditions tested were: 8 and 12 MPa; 22, 30, 35, 40 and 45 °C; with treatment times ranging from 5 to 60 min, and were chosen based on previous findings (Spilimbergo and Ciola, 2010a). For the qualitative characterizations, the same process conditions were applied to a larger volume (about 100 ml) of coconut water based on previous findings (Gasperi et al., 2009).

2.2.2. Heat treatment

Heat pasteurization (HP) equipment consisted of a water bath (Dubnoff Bath-BSD/D, International PBI, Milano, Italy) with an agitated platform where 200 ml jars of coconut water were placed. The pasteurization of the coconut water was performed at 72 °C for 5 and 10 min and 90 °C for 1, 3, 5, 10 and 20 min. The process conditions were chosen based on literature findings (Reddy, 1995). After the treatments, the samples were cooled down in a water bath placed in a refrigerated chamber, in order to speed up the cooling process and decrease the time they were exposed to high temperatures, trying to minimize the temperature's impact on their quality attributes. Subsequently the samples were stored at 4 °C until microbial analysis was performed.

2.2.3. Microbial analysis

The microbial analyses were performed using the plate count method. The sample was serially diluted in a phosphate buffer