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Enhancement of UVC-light treatment of tangerine and grapefruit juices through ultrasonic atomization

Oscar Antonio-Gutiérrez, Aurelio López-Malo, Nelly Ramírez-Corona *, Enrique Palou

Departamento de Ingeniería Química, Alimentos y Ambiental, Universidad de las Américas Puebla, San Andrés Cholula, 72810, Puebla, Mexico

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ABSTRACT

The objective of the study was to combine shortwave ultraviolet irradiation (UVC-Light) with ultrasonic atomization (UA) to generate microdroplets by atomizing the juices to enhance contact with UVC-Light and to evaluate its effect on the inactivation of *Saccharomyces cerevisiae* as well as on selected physicochemical parameters of tangerine and grapefruit juices. UVC lamps and an ultrasonic atomizer were used individually and in combination. The effect of lamps' orientation (horizontal or vertical) and the number of lamps (1 or 2) were assessed. No significant ($p > 0.05$) changes on pH, °Bx, and color of studied juices were observed, since the contact time of the microdroplets with the UVC-Light was short. After processing 250 mL of juice, microbial population was reduced by 0.84 log cycles when using a single UVC lamp combined with UA while a 2.8 log cycles reduction was observed after three passes. Tested configurations with two lamps did not achieve effective inactivation of *S. cerevisiae*, possibly because the generated microdroplets were not in close contact with UVC-light as was the case with one lamp.

Industrial relevance: The ultrasonic atomization for the UVC-treatment of juices was assessed for the first time in this work. The ultrasonic atomization of juices may be suitable for the inactivation of yeasts when combined with UVC-Light as long as atomization takes place near the irradiation site. These combined technologies have the potential to generate foods minimally processed.

1. Introduction

Nowadays, consumers prefer minimally processed foods with similar characteristics to their fresh counterparts, without preservatives, and wholesome (Sun, 2014). Emerging technologies such as ultrasound (US) and short-wave ultraviolet irradiation (UVC-Light) have been studied to obtain minimally processed products. Ultraviolet irradiation covers wavelengths from 180 to 400 nm, while UVC is located between 200 and 280 nm. UVC-Light with a wavelength of 254 nm is currently used to disinfect water and surfaces. UVC-Light damages cellular DNA by promoting the formation of bonds between thymine molecules; these dimers hinder DNA replication (Adams & Moss, 2008). This technology has been used to disinfect juices such as orange, strawberry, guava (Keyser, Műller, Cilliers, Nel, & Gouws, 2008), apple (Caminiti et al., 2012) and pineapple (López-Díaz, López-Malo, & Palou, 2013), among others; nevertheless, multiple lamps or long processing times are needed, which could affect the sensory and nutritional characteristics of treated juices (Torkamani & Niakousari, 2011).

On the other hand, ultrasound (US) is defined as the process by which acoustic waves with frequencies above 16 kHz are generated (Arroyo, Cebrián, Pagán, & Condón, 2011). The effect on microorganisms is given by the conditions of pressure and temperature during the process and is attributed to the collapse of bubbles known as cavitation (Earnshaw, 1998). Tiwari, O'Donnell, and Cullen (2010) processed grape juice with ultrasound and analyzed losses of anthocyanins and color changes, concluding that ultrasound had minimal effects on these characteristics. Athmaselvi (2010) found that ultrasound was not effective to treat papaya juice inoculated with various microorganisms, because long processing times (at least 20 min) were required for proper inactivation, which generated an increase in temperature, causing the loss of several bioactive compounds (Rawson et al., 2011). To minimize negative effects on juices, such as loss of vitamins, or to reduce processing times, some researchers have combined UVC-Light with other technologies such as US (Gayán, Condón, & Álvarez, 2014). Several studies have shown that the time to inactivate various microorganisms is lowered by combining these technologies (Birmpa, Sfika, & Vantarakis, 2013; Gómez-Díaz, Santiesteban-López, Palou, & López-Malo, 2011; Khandpur & Gogate, 2015a). Still, there are certain challenges to be solved such as minimizing changes in color and/or flavor, and achieving greater microbial reductions in less time. One way to achieve greater contact between UVC-Light and the juice, but without increasing the processing time, is by spraying the juice. It is known that the generation of droplets produces a larger contact area,

* Corresponding author.
E-mail address: nelly.ramirez@udlap.mx (N. Ramírez-Corona).

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and as the size of the drop decreases, the surface area per unit mass increases, a principle used in spray drying (Hurtado, 2003). In this work, the atomization of juices was performed with an ultrasonic atomizer and coupled with UVC-Light in order to determine the effect of the combination of these technologies on different physicochemical parameters of tangerine and grapefruit juices, and its effect on the inactivation of *Saccharomyces cerevisiae*.

2. Material and methods

2.1. Inoculum preparation

S. cerevisiae was obtained from the Food Microbiology Laboratory of the Universidad de las Américas Puebla and periodically plated on potato dextrose agar (PDA). A loopful of yeast colonies from PDA slants was transferred to 50 mL of Sabouraud dextrose broth (BD Difco™, MD, USA), the yeast was incubated at 35 °C until it reached its stationary phase (48 h), attaining a population of approximately 10^6 CFU/mL (Gómez-Díaz et al., 2011). This procedure was repeated, as often as necessary to have a fresh inoculum for each treatment.

2.2. Preparation of the juices and physicochemical analysis

Commercial pasteurized grapefruit and tangerine juices were bought at a local market in San Andres Cholula, Puebla, México. For the preparation of juices, 25 mL of yeast broth were added to 225 mL of juice, and the mixture was maintained at 25 °C in a water bath before treatment. The pH was measured with a digital potentiometer (PH10, Conductronic, Puebla, México). The total soluble solids, expressed as °Brix, were determined with a digital refractometer (PR-101, ATAGO®, Tokio, Japon). Color was measured with a colorimeter (CR-400 Konica Minolta, Nieuwegein, Netherlands) adjusted to operate with D_{65} lightning and 2° observation angle and using a white plate as background. Samples were placed inside a glass cell (model CM-A98, Konica Minolta, Nieuwegein, Netherlands) with an optical path of 10 mm (4 cm of height for measurement). The parameters *L*, *a*, and *b* on the Hunter scale were obtained.

2.3. Ultrasonic atomization treatment

An ultrasonic atomizer (20 kHz, VCX 130, Sonics & Materials, CT, USA) was used, working at 100% of amplitude, with a titanium tip that generated a median drop size of 90 μm (according to the manufacturer), which was placed vertically (Fig. 1a). The previously inoculated juices were stirred and pumped into the top of the nozzle with a peristaltic pump (Master Flex 7553-71, Cole-Parmer®, IL, USA) at a flow rate of 1.1 mL/s. The treated juices were collected in a sterile beaker and processed a total of three times. Each time that the juice was processed, it was considered as one pass, giving a total number of three passes. The same applies for the following treatments. Before each pass, the system was rinsed with 500 mL of sterile water.

2.4. UVC-light treatment

An UVC lamp (G37T6VH, Light Sources, CT, USA) of 24 cm of length and 2.5 cm of diameter was placed in a stainless steel tube (5 cm diameter and 35 cm in length) oriented vertically (Fig. 1b). The previously inoculated juice was stirred and pumped into the top of the tube at a flow rate of 1.1 mL/s. At the exit tube, the treated juice was collected in a sterile beaker and processed a total of three times (three passes). Before each pass, the system was rinsed with 500 mL of sterile water.

2.5. Combined treatments

The equipment mentioned before was used with the same specifications. For configuration 3 (Fig. 1c) one UVC lamp was used vertically and the ultrasonic atomizer nozzle was placed at the top, with the tip into the stainless steel tube, to keep the juice to no >1 cm from the lamp. In configuration 4 (Fig. 1d) two lamps were used in a vertical orientation spaced 10 cm from each other and the ultrasonic atomizer nozzle

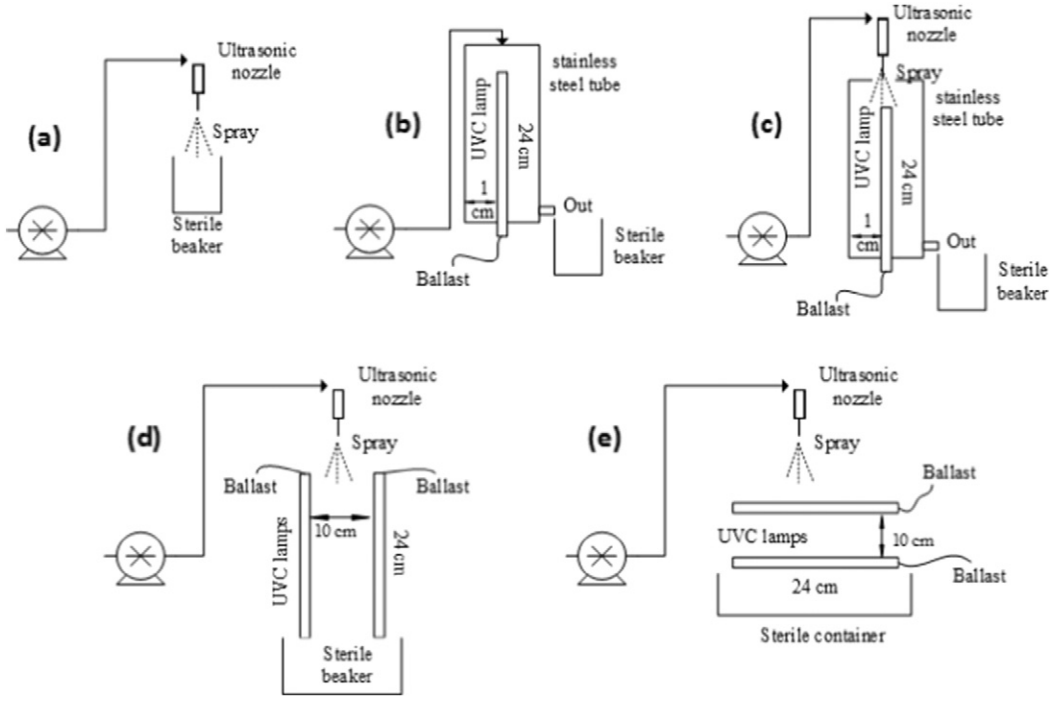

Fig. 1. Configurations studied in the treatment of juices. (a) Configuration 1, ultrasonic atomizer system. (b) Configuration 2, UVC lamp system. (c) Configuration 3, one UVC lamp with the ultrasonic atomizer nozzle at the top and into the stainless steel tube (d) Configuration 4, two UVC lamps in vertical orientation with the ultrasonic atomizer nozzle at the center top without stainless steel tube covering. (e) Configuration 5, two UVC lamps in a horizontal orientation and the ultrasonic atomizer nozzle at the center top without stainless steel tube covering.