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Changes in quality characteristics of fresh-cut jujubes as affected by pressurized nitrogen treatment

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ABSTRACT

When fresh-cut jujubes are subjected to pressurized nitrogen treatments, the nitrogen gas dissolves into water and forms clathrate hydrates which ultimately lead to restriction in water mobility. Fresh-cut jujubes were, respectively, treated with 1.0 MPa nitrogen, 1.5 MPa nitrogen, 1.9 MPa nitrogen and 1.9 MPa air for 30 min at 4 °C and without pressurized treatment(control) and then stored at 4 °C and 80 % relative humidity (RH) for 12 days. Physiological, textural, chemical, and microbial attribute were determined every 2 days. Results indicated that pressurized nitrogen treatments carried out at 1.5 MPa successfully inhibited respiration, water loss, softening, chlorophyll degradation, and color change. The treatments also significantly reduced loss of ascorbic acid and soluble solids. Treated fresh-cut jujubes carried significantly less microbial population. Thus, it was concluded that pressurized nitrogen treatment was beneficial to preserve quality of fresh-cut jujubes.

1. Introduction

Due to increased awareness in healthy diet and fast-paced lifestyles, the demand for fresh-cut fruits such as fresh-cut jujube has increased (Mao, Lu, & Wang, 2007; Ahmed, Martin-Diana, Rico, & Barry-Ryan, 2012). Nevertheless, shelf life of fresh-cut products is commonly limited by their quality deterioration during storage. Thus, it is essential that food researchers provide safe and maintained natural texture and flavor of fresh-cut products as much as possible. In many studies, Mild heat treatment has been used for fresh-cut produce (Roura, Pereyra, & del Valle, 2008; Lemoine, Civello, Chaves, & Martínez, 2009; Silveira, Aguayo, Escalona, & Artés, 2011; Siddiq, Roidoung, Sogi, & Dolan, 2013). Nevertheless, mild heat treatment leads to reduction of nutritional components and browning of fresh-cut produce (Djioua et al., 2009; Alegre, Vinas, Usall, Anguera, & Abadias, 2011; Alegria et al., 2012; Sgroppo & Pereyra, 2009). Ultraviolet C radiation (UV-C) treatments have been used as an alternative to thermal treatments for sterilization, thus preserving the quality of fresh-cut fruits (Fonseca & Rushing, 2006; Artes-Hernandez, Robles, Gomez, Tomas-Callejas, & Artes, 2010; Du, Avena-Bustillos, Breksa, & McHugh, 2012; Kasim, Kasim, & Erkal, 2008; Manzocco, Da Pieve, & Maifreni, 2011). Nonetheless, there are many defects of UV light on fresh-cut fruits, including surface browning and variation of flavor. Ozone is generally recognized as safe in the United States for food contact applications (Zhang, Lu, Yu, & Gao, 2005). Owing to its sterilization function, ozone has been applied to reduce microbial populations and extend the expiration date of many fresh-cut fruits (Selma, Allende, Lopez-Galvez, Conesa, & Gil, 2008). Nevertheless, a weakness of ozone is its inferior stability in the presence of organic matter (Bermúdez-Aguirre & Barbosa-Cánovas, 2013).

Nowadays, gas-based food preservation technology has been preferably used to preserve quality of fresh-cut fruits (Wu & Zhang, 2011).When gases such as xenon and nitrogen are dissolved in water under appropriately selected temperature and pressure condition, water molecules form a cage of polyhedral structure that can hold gas molecules, known as the clathrate hydrate (Chatti, Delahaye, Fournaison, & Petitet, 2005; Linga, Kumar, & Englezos, 2007; Anderson, 2007; Disalvo et al., 2008; Zhang, Zhan, Wang, & Tang, 2008; Ando et al., 2009; Ruffine, Donval, Charlou, Cremière, & Zehnder, 2010; Wu, Zhang, & Adhikari, 2012).Some studies suggested that mobility of water in fruits and vegetables can be greatly restricted due to the formation of clathrate hydrate (Zhan, 2005; Meng, Zhang, Zhan, & Adhikari, 2013). The method of structured water was effective in extending vase life of cut carnations treated with Xe (Oshita, Seo, Kawagoe, Koreeda, & Nakamura, 1996). Both Xe and nitrogen are chemically stable, and they do not have an adverse effect in humans (Makino et al., 2006; Ronald, 2001; EU, 2012; Wu et al., 2012; Wu, Zhang, & Wang, 2012c; Meng et al., 2013). Thus, the technology of gas-based food preservation is a useful method for extending the shelf life of fruits. Currently, the technology is at the initial exploratory stage in the fresh-cut fruits industry, while there are very few relevant reports all around the world (Oshita et al., 1996; Rahman, Islam,

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Khair, & Bala, 2002; Shan, Shan, Tian, Zhang, & Zhan, 2008; Zhang et al., 2008; Yang et al., 2010; Wu & Zhang, 2011; Alegre et al., 2011; Alexandre, Santos-Pedro, Brandáo, & Silva et al., 2011; Manzocco et al., 2011a; Xing et al., 2011; Pan and Zu, 2012; Meng et al., 2013). Fresh jujube, which originated from China, is a nutritional fruit. It is one of the crucial fruits in China for its special nutritional and medical values. However, there is no information available on the effect of pressurized N_2 on the quality of fresh-cut jujubes.

In this context, the goal of this research was to study the effect of pressurized nitrogen on the quality of fresh-cut jujubes in low storage. The effects of pressurized nitrogen on the storage quality parameters such as color, ascorbic acid, soluble solids, firmness, loss of water, and soluble solids, respiration rate, and microbial quantity were measured.

2. Materials and methods

2.1. Materials

“Red date” jujubes (Chinese date) were purchased from a supermarket in the neighborhood of Shaanxi University of Science and Technology. Jujubes were selected to remove defective jujubes.

2.2. Sample preparation and processing

Whole jujubes were cleaned with deionized water and sliced into 3-cm-long quarters with a knife in a clean room maintained at 4 °C. Subsequently, fresh-cut jujubes were washed with sodium hypochlorite (90 μL L^{-1} NaClO, pH 6.5) for 120 s and washed five times with distilled water. Then, these samples were gently centrifuged at(110 × *g* for 1 min) in order to remove the water used in washing. They were further cut into small pieces with thickness of 20 mm and then placed into pressure vessels and subjected to pressurized nitrogen.

According to a former study (Meng, Zhang, & Adhikari, 2012b), the treatments were divided into four groups: (1) control: without pressurized treatment, (2) 1.9 MPa air: treatment with pressurized air at 1.0 MPa and 25 °C for 30 min, (3) 1.0 MPa nitrogen: treatment with pressurized nitrogen at 1.0 MPa and 2 °C for 30 min, (4) 1.5 MPa nitrogen: treatment with pressurized nitrogen at 1.5 MPa and 25 °C for 30 min, and (5) 1.9 MPa nitrogen: treatment with pressurized nitrogen at 1.9 MPa and 25 °C for 30 min. Fresh-cut jujubes were enclosed in a high pressure gas treatment equipment.

The high pressure gas treatment equipment was manufactured by Huaan Scientific Research Instrument Co., Ltd. (Jiangsu, China). The schematic diagram of the processing equipment is shown in Fig. 1. The essential components of the equipment consist of a 1000 mL stainless steel treatment vessel, a plunger pump, a vacuum pump, and a temperature-controlled water bath. The sample treatment vessel had two circular viewing windows in the front and back. This vessel was submerged in a water bath. The water in the bath was re-circulated through a plastic tube to a controlled bath. A plunger pump was used to pressurize the vessel. A pressure transducer was fixed in the vessel lid. The data of temperature and pressure were displayed on a control panel. The equipment had ideally gas-tight connections to the gas inlet and outlet. The vessel lid was sealed during HP gas processing. A vacuum pump was connected for evacuating the vessel. Gas was injected into the plunger of the pressurizer from a gas cylinder and brought into the pressure vessel. The on–off valve on the feed line between the pump and the vessel was turned off after the required pressure level was reached. Once the desired level of pressure was reached, this pressure was held for the required treatment time. After completion of the experiments, the processing equipment was depressurized and the pressure was brought to atmospheric pressure by opening the on–off valve on the vessel's outlet line. Jujube slices were placed into the treatment vessel. For HP N_2 treatment, the vessel containing jujube slices was sealed, vacuumized, and then flushed with N_2. The designed pressure was held for 30 min at 25 °C. After treatment, the jujube slices were immediately packaged and stored at 4 °C.

2.3. Respiration rate

Fresh-cut jujubes of 200 g were placed into 1,500-mL glass jar for 1 h at 4 °C. A 2-mL headspace gas sample was taken with a gas-tight syringe and injected into gas chromatographs (Shimadzu GC-2010, Kyoto, Japan). The gas chromatography (GC) settings for the detection of CO_2 were as follows: a thermal conductivity detector (TDC), column temperature of 55 °C, and carrier gas (helium) flow rate of 30 mL/min. Respiration rate was calculated as mg CO_2/(kg h).

2.4. Water loss and firmness

Water loss of fresh-cut jujubes was determined by difference in mass of the sample before and after storage and expressed in wet basis (percent). Firmness was determined with a TA-XT2i Texture Analyzer (Stable Micro Systems Ltd., Surrey England, UK) by measuring the maximum force (N) required to impale the flesh at a speed of 6 mm s^{-1} to a depth of 10 mm. The texture analyzer equipped with a stainless

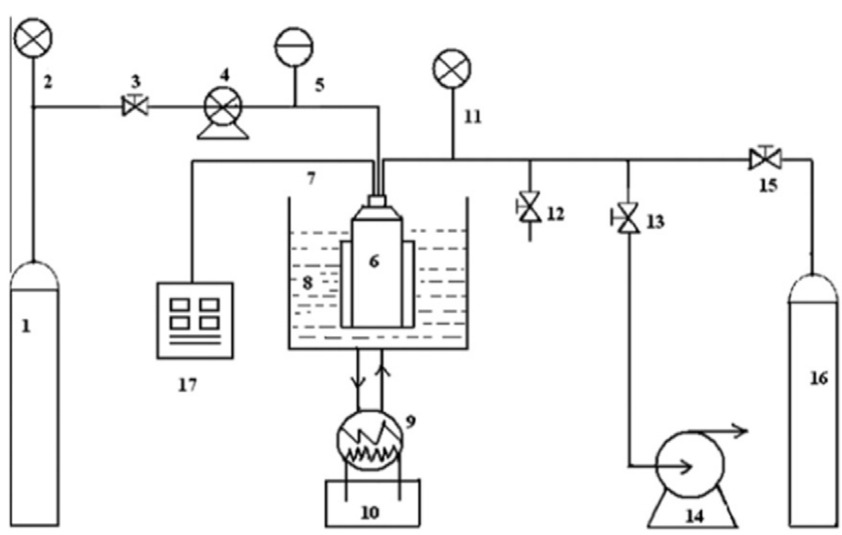

Fig. 1. Schematic diagram of the processing equipment. 1: Gas bottle; 2: pressure meter; 3: on–off valve; 4: plunger pump; 5: pressure sensor; 6: high pressure vessel; 7: thermocouples; 8: water bath; 9: thermostatic bath; 10: cold compressor; 11: pressure gauge; 12: relief valve; 13: on–off valve; 14: a vacuum pump; 15: vent valve; 16: exhaust gas cylinder; and 17: displaying board.