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A short-term carbon dioxide treatment inhibits the browning of fresh-cut burdock

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ABSTRACT

Fresh-cut burdock is susceptible to browning. The effect of short-term carbon dioxide (CO_2) treatment on inhibiting browning of fresh-cut burdock during storage at 2–4 °C was investigated. The results showed that the burdock slices treated with CO_2 for 4 h, 6 h and 8 h exhibited better visual quality during 8 d storage, compared with the ones treated with air. CO_2 treatment for 6 h on the fresh-cut burdock slices reduced the respiration rate, lowered the activity of PPO and PAL, and the content of total phenolic compounds. On the other hand, CO_2 treatment increased the content of H_2O_2, enhanced the activity of CAT, POD, and SOD, maintained DPPH inhibition rate and decreased the content of MDA. The results indicate that the short-term pure CO_2 treatment can extend the shelf life of fresh-cut burdock by inhibiting its browning and improving its quality.

1. Introduction

Fresh-cut burdock has been gradually recognized to have high potential because of the high nutritional value and biological properties (Chow et al., 1997; Duh, 1998; Chen et al., 2004). The white flesh of fresh-cut burdock root is very susceptible to browning which could limit the shelf life and decrease the nutritional value and visual quality (Tomás-Barberán and Espín, 2001). A research studied the fresh-cut burdock roots treated with 3% citric acid, 3% sodium chloride, 0.3% cystein and 3% sodium acetate to inhibit browning (Chung et al., 2012). Zhu et al. (2009) had studied the effects of the $Ca(AsA)_2$ and 4-hexylresorcinol (4-HR) on browning and quality of fresh-cut burdock. However, consumers nowadays tend to avoid the chemical additives due to potential harmful effects (Kim et al., 2014). The utilization of non-toxic, cheap, residue-free and environmentally friendly gases to retard the browning, preserve the quality and extend the shelf life of fruits and vegetables has become the main focus of consumers and researchers. CO_2, as a low-cost, odorless, tasteless and colorless gas, represents a novel approach to non-thermally inactivate undesirable enzymes and preserve the overall quality of fresh-cut produce. CO_2 has been reported to decrease respiration rates, retard senescence, reduce or delay the overall enzymatic activity and alleviate physiological disorders (Aharoni et al., 1989; Kader et al., 1989; Day, 1994). Moreover, low respiration rate made the activity of phenylalanine ammonia lyase (PAL) decrease (Ke and Saltveit, 1989), which is the catalyst in the first step of phenylpropanoids biosynthesis (Jones, 1984), and thus affects the synthesis of phenolic compounds.

Polyphenolic oxidase (PPO) is considered as a key enzyme in enzymic browning, which oxidize ortho-phenolsto quinones under the action of oxygen (Kavrayan and Aydemir, 2001; Eidhin et al., 2006). Peroxidase (POD) is another main enzyme in addition to PPO that functions in enzymatic browning (Yingsanga et al., 2008), browning mediated by which is different from PPO-mediated browning related to the hydrogen peroxide (H_2O_2) generation with ongoing of PPO-mediated reactions (Toivonen and Brummell, 2008). Besides, catalase (CAT), as the H_2O_2 quenching agent had been demonstrated to form the biological defense system together with POD and superoxide dismutase (SOD) (Huang et al., 2005; Zhang and Tian, 2007) as they can eliminate free oxygen radicals (Peng et al., 2006). Membrane stability is also a major factor affecting browning rate for the compartmentalization of phenolic compounds and associated enzymes (Toivonen and Brummell, 2008) as fresh-cut processing easily disrupts cellular membranes, which causes lipid peroxidation and forms

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malondialdehyde (MDA), contributing to the deterioration and browning of the fresh-cut burdock (Duh, 1998).

Low and high O_2/CO_2 atmospheres could reduce respiration rate and browning in minimally processed potatoes (Angós et al., 2007) and retard discoloration effectively in fresh-cut jicama (Aquino-bolanos et al., 2000). High CO_2 concentration alter intracellular pH and metabolic regulation, inhibits enzymes of phenolic metabolism and delays browning in lettuce tissues (Siriphanich and Kader, 1985). However, there is no report yet on the application of high concentration of CO_2 for controlling browning of fresh-cut burdock.

The objective of this research was to determine the possible application of CO_2 as an anti-browning method for the fresh-cut burdock by evaluating its effects on the changes in visual quality and the physiological parameters.

2. Materials and methods

2.1. Raw material and sample preparation

Burdock (*Arctium lappa* L.) purchased from Yangtze River Agriculture Co., Ltd., Weifang, Shandong Province, China, was immediately transported to the laboratory. The experiment used a batch of good quality burdock, selected with a diameter of about 3 cm and a length of 80 cm without injury and hollowness. The burdock was washed in tap water, rinsed in sodium chlorinated solution (200 $\mu L\,L^{-1}$ NaClO) for 5 min to reduce the surface contamination, hand-peeled and cut diagonally into 3 mm slices. The burdock slices were immediately rinsed in 50 $\mu L\,L^{-1}$ NaClO solution for 5 min, dried by draining and blotting with cheesecloth, and packed into 100 cm × 120 cm polyethylene (PE) plastic bags. The air in the bag was removed by gently squeezing it. CO_2 gas with purity over 99.9% (Spring Company, Taian, Shandong province, China) was passed through a wet cloth gauze for maintaining higher humidity, then through each bag from one side of the bag and out from the other side with appropriate flow rate to keep the bags fully inflated. Samples were treated for 4 h, 6 h and 8 h at 10 °C. The treated slices (2.5 kg) and the control non-treated slices (2.5 kg) were packed into 40 cm × 80 cm PE bags respectively and stored at 2–4 °C. The samples were evaluated for quality, physiological and biochemical changes after 0, 2, 4, 6 and 8 d during the storage after CO_2 treatment. For physiological and biochemical evaluations, only burdock slices treated with CO_2 for 6 h were used and each sample had three replications for analysis.

2.2. Visual quality assay

2.2.1. Sensory evaluation

The overall visual quality was evaluated on a 9–1 scale as described by Amodio et al. (2007). The sensory evaluation standard was as follows: 9 equaled excellent, with no defects; 7 equaled good, with minor defects; 5 equaled fair, with moderate defects; 3 equaled poor, with major defects; and 1 equaled unusable. A score of 6 was considered to be the limit of salability and the shelf-life was defined.

2.2.2. Color measurement

The L^* (lightness), a^* (reddish–greenish) and b^* (yellowish–bluish) indice of the CIELAB colorimetric system were used to evaluate the color change of the burdock samples (Abbott, 1999). The surface color change of slices was determined by the CIE L^*, a^*, b^* scale using a colorimeter (CR-400, Minolta Co., Osaka, Japan) and calibrated on a standard white tile ($L^* = 97.06$, $a^* = 0.04$, $b^* = 2.01$) before measured. Ten individual slices of each sample were measured twice (once on each side) at various time intervals.

2.3. Analysis of respiration rate

Burdock slices (100 g) from the CO_2 treatment for 6 h were placed into LOCK plastic boxes (150 × 95 × 85 mm, Shanghai Lock trade Co., LTD) and sealed for 4 h to measure the concentration of CO_2 at 0, 2, 4, 6 and 8 d during the storage to examine the respiration rate. The volume of CO_2 was 1.0 L and its concentration was measured by a CO_2 analyzer (PBI-940437B, PBI Dansensor, Denmark) and the respiration rate was calculated following the method of Castelló et al. (2006) and CO_2 production rate expressed as $\mu g\,kg^{-1}\,s^{-1}$. Three replications of each sample were conducted.

2.4. Physiological and biochemical assays

Burdock slices selected randomly were collected at 0, 2, 4, 6, 8 d during storage after the 6 h CO_2 treatment, frozen immediately with liquid nitrogen, ground into powder with a liquid nitrogen grinding apparatus (IKA A11 basic; IKA Werke GmbH & Co., KG, Staufen, Germany), and then stored at −80 °C until measurement.

2.4.1. Determination of total phenolics

The total phenolic content was measured according to the Folin–Ciocalteu procedure (Singleton and Rossi, 1965), with some modifications. Burdock powder (2.5 g) were mixed with 10 mL of 70% acetone and incubated for 2 h at 25 °C. The sample was then centrifuged at 11,140 × *g* for 10 min at 4 °C, and the supernatant was used for analysis. For analysis, 0.2 mL of the supernatant was mixed with 0.5 mL of the Folin–Ciocalteu reagent. After mixing thoroughly for 3–4 min, 0.5 mL of 10% Na_2CO_3 solution was added into the mixture. The volume was then brought to 10 mL with water. After 1 h at room temperature, the absorbance was measured at 765 nm with a UV-spectrophotometer (TU1810, Beijing Purkinje General Instrument Co., Ltd., China). The absorbance of different gallic acid concentrations was used as the standard to determine the concentration of the total phenolic compounds of the burdock samples.

2.4.2. Assessment of PAL activity

PAL activity was measured as previously described by Martínez-Téllez and Lafuente (1997), with slight modifications. Burdock powder (2.5 g) were placed in a plastic test tube containing 0.25 g soluble PVPP, then mixed with 10 mL of 50 mmol L^{-1} borate buffer (pH 8.5). The sample was centrifuged at 11,140 × *g* for 20 min at 4 °C, and the supernatant was used for analysis. The reaction mixture in the testing tubes included 2 mL buffer (pH 8.5), 2 mL of 20 mmol L^{-1} phenylalanine and 0.1 mL of enzyme solution. The tubes were incubated at 40 °C for 1 h. Absorbance was measured at 290 nm. One unit of PAL activity was defined as an increase of 0.01 absorbance units in one minute by the amount of the enzyme. The enzyme activity was expressed on a fresh weight basis as units kg^{-1}.

2.4.3. Assessment of polyphenol oxidase (PPO) activity

PPO activity was determined with some modifications to the procedure mentioned by Galeazzi et al. (1981). Burdock powder (2.5 g) were weighed into a plastic test tube containing 0.25 g insoluble polyvinylpolypyrrolidone (PVPP), mixed with 10 mL phosphate buffer (pH 6.8), centrifuged at 11,140 × *g* for 20 min at 4 °C, and the supernatant was used for analysis. The reaction mixture consisted of 0.1 mL of crude enzyme extract solution, 2.5 mL of 0.2 mol L^{-1} phosphate buffer (pH 6.8) and 0.5 mL of 20 mmol L^{-1} catechol solution. Enzyme activity was measured every five seconds for one minute by measuring the absorbance at 410 nm. One unit of enzyme activity was defined as the increase in absorbance by 0.01 per minute under assay conditions. The