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ScienceDirect

Postharvest Biology and Technology 49 (2008) 287–293

Postharvest Biology and Technology

www.elsevier.com/locate/postharvbio

Responses of minimally processed leeks to reduced O_2 and elevated CO_2 applied before processing and during storage

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Received 10 November 2007; accepted 2 January 2008

Abstract

To study the effects of storage atmosphere on the main quality attributes of minimally processed leeks, stalks were stored in air, 1, 3 or 5% O_2 in N_2, 6, 11 or 17% CO_2 in air, or 1% O_2 + 14% CO_2 in N_2 at 6.5 °C for 14 days. In addition, other leeks were subjected to a preprocessing treatment consisting of exposure to air or 1% O_2 + 14% CO_2 at 6.5 °C for 0, 12, or 24 h prior to minimal processing and storage in air or 1% O_2 + 14% CO_2 at 6.5 °C for 14 days. Leaf and root growth, number of newly formed roots, color changes at the basal cut surface as well as on the white and green leaf tissue, fresh weight loss, and enzymatically produced pyruvic acid content were determined. Storage of minimally processed leek stalks in 1% O_2 at 6.5 °C for 14 days minimized leaf and root growth as well as color changes at the center of the basal cut surface, but did not prevent peripheral discoloration of the basal cut surface; the other reduced O_2 and elevated CO_2 treatments were less effective than 1% O_2 in reducing leaf and root growth and cut surface discoloration. Storage in 1% O_2 + 14% CO_2, however, resulted in an additional beneficial effect compared with 1% O_2 alone by preventing the appearance of peripheral discoloration on the basal cut surface. Exposure to 1% O_2 + 14% CO_2 at 6.5 °C for 12 or 24 h prior to processing did not further contribute to quality maintenance of minimally processed leeks during storage in either air or 1% O_2 + 14% CO_2 at 6.5 °C for 14 days.

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Keywords: *Allium porrum* L.; Preprocessing treatment; Quality; Inner leaf growth; Color; Pyruvic acid; Enzymatically produced pyruvate

1. Introduction

Minimal processing of leek stalks includes root trimming, removal of outer damaged or decayed leaves and trimming to a desired length. Postharvest quality deterioration of minimally processed leeks includes inner leaf growth and discoloration of the cut surface, as well as fresh weight loss (Tsouvaltzis et al., 2006a, 2007). Such deterioration is significantly reduced by storage at 0 °C (Tsouvaltzis et al., 2006a) and is effectively controlled by a prestorage hot water treatment (Tsouvaltzis et al., 2006b), although in the latter case a higher fresh weight loss of the treated stalks is induced. On the other hand, storage at 0 °C is practically inapplicable, since in commercial practice minimally processed produce is most commonly prepared, shipped, and stored at 5–10 °C (Watada et al., 1996).

Leeks are favored for their unique and mildly pungent flavor. The aroma profile of fresh leek is dominated by pungent sulfur-containing volatiles originating from the alliinase (EC 4.4.1.4)-catalyzed decomposition of odorless non-volatile precursors to form sulfenic acids, which are highly reactive and combine quickly to form the thiosulfinates that are responsible for the odor of freshly cut leeks (Nielsen and Poll, 2004). The pungency of leeks can increase during storage, as in onions (Uddin and MacTavish, 2003), but a controlled atmosphere (CA) of 2% O_2 + 8% CO_2 has been shown to reduce onion pungency during storage (Uddin and MacTavish, 2003). Enzymatically produced pyruvate (EPP) is a reliable indicator of pungency and it is a stable product of the hydrolysis of S-alk(en)yl-L-cysteine sulfoxides (ACSOs) by alliinase that occurs when the cells of Allium crops are disrupted (Chope et al., 2006).

Storage in reduced O_2 and/or elevated CO_2 atmosphere conditions, in active or passive modified atmosphere packaging (MAP), has been reported to result in beneficial effects on the quality of minimally processed fruits and vegetables (Brecht et

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doi:10.1016/j.postharvbio.2008.01.006

al., 2004). Leaf extension growth was retarded in minimally processed green onions stored in 0.2% and/or 7.5% CO_2 at 5 °C (Hong et al., 2000). Leaf growth of minimally processed green celery stored at 4 °C was also negatively correlated with CO_2 concentration in the storage atmosphere (Gómez and Artés, 2004). Also, Gariépy et al. (1984, 1994) has reported that color and fresh weight are retained in intact leeks stored in 2.2–2.7% O_2 + 3.5–4.9% CO_2 at 1.5 °C for 5 months. However, there are no reports on quality deterioration of minimally processed leeks during storage in reduced O_2 and/or elevated CO_2.

Furthermore, Tsouvaltzis et al. (2006a) showed that inner leaf growth of minimally processed leeks is initiated within the first hour after processing (cutting of the stalk). Though a preprocessing treatment with hot water has been reported to minimize post-processing inner leaf growth initiation (Tsouvaltzis et al., 2006b), there are no data available on the application of reduced O_2 and/or elevated CO_2 as a preprocessing treatment.

Therefore, the aim of this study was to evaluate the effect of storage of minimally processed leeks in different reduced O_2 and/or elevated CO_2 concentrations, as well as the effect of a preprocessing exposure to reduced O_2 plus elevated CO_2 on the control of quality deterioration of minimally processed leeks. Furthermore, knowledge of minimally processed leek O_2 and CO_2 tolerance as well as the beneficial effects of reduced O_2 and/or elevated CO_2 atmospheres can be useful for application to MAP design for this product.

2. Materials and methods

2.1. Plant material

Leeks (*Allium porrum* L.) were grown in California, hand-harvested, hydrocooled, and package-iced in waxed fiberboard cartons. Then they were shipped by refrigerated truck to a supermarket distribution center located approximately 110 km from Gainesville. The leeks were obtained immediately upon their arrival at a local supermarket on the day after their arrival at the Florida distribution center. After being transferred to the Postharvest Facilities at the University of Florida, the leeks were sorted so that damaged stalks were discarded. During May to July 2006 experiments were conducted three times, with each experiment designed based on the results of the previous experiment and with similar results recorded for repeated treatments; two experiments conducted using the final set of leeks are presented here.

2.2. Treatments

For the first experiment, the outer leaves were removed and the stalks were washed in tap water and dried with a paper towel before the roots were removed by cutting with a sharp knife. The stalks were then trimmed to 15 cm from the base, weighed, and their color was measured. Then, 12 individual stalks per treatment were placed in a 10-L jar and held at 6.5 °C for 14 d. Gas mixtures of 1.02 ± 0.03, 3.07 ± 0.03 or 4.88 ± 0.04% O_2 in N_2, as well as 6.35 ± 0.36, 11.38 ± 0.52 or 16.59 ± 0.77% CO_2 in air (1, 3, or 5% O_2 and 6, 11, or 17% CO_2, respectively) were passed through the jars at a rate of 90–140 mL min^{-1}. Air was also used as the control. Incoming O_2 and CO_2 concentrations were monitored using a PBI Checkmate O_2 and CO_2 analyzer (Topac, Hingham, MA, USA) with zirconium and infrared detectors, respectively, and were adjusted daily to the desired levels. High humidity was established inside the jars by bubbling the air or gas mixtures through water before entering the jars.

For the second experiment, the stalks were cut to 22 cm from the base and they were divided into two lots. For the first lot, 10 individual stalks per treatment were cut to 15 cm from the base, placed in 10-L jars and kept at 6.5 °C for 14 d. Air or a gas mixture of 1.15 ± 0.10% O_2 (1% O_2), 14.48 ± 0.66% CO_2 (14% CO_2), or 1.19 ± 0.09% O_2 + 14.46 ± 0.11% CO_2 (1% O_2 + 14% CO_2) was passed through the jars.

For the second group, 10 individual stalks per treatment were placed in 10-L jars and kept at 6.5 °C for 0, 12, or 24 h. Air or a gas mixture of 1.19 ± 0.09% O_2 + 14.46 ± 0.11% CO_2 (1% O_2 + 14% CO_2) was passed through the jars (preprocessing treatment). After the preprocessing treatment, the outermost leaves were removed from the stalks, which were then washed in tap water and dried with a paper towel before the roots were removed and the stalks cut to 15 cm from the base. The trimmed stalks were weighed, their color measured, and they were transferred back into the jars and held for 14 d under the same atmosphere conditions.

At the end of the storage period, the stalks were weighed, their color was measured, growth phenomena were determined (inner leaf growth, number of newly formed roots, and root growth; see below) and they were then placed at −30 °C for EPP determination.

2.3. Growth phenomena determination

Inner leaf growth was measured from the base to the end of the most extended leaf (maximum leaf growth). The number of newly formed roots was counted and their length was measured.

2.4. Color measurement

Color changes were quantified in the L^*, a^*, and b^* color space using a Minolta colorimeter (Model CR-200b, Minolta Corp., Ramsey, N.J.), equipped with an 8-mm diameter measuring head. Color measurements were made at the center of the basal cut surface as well as at two locations on the surface of the outermost leaf: (a) 1 cm above the basal cut (lower white part) and (b) 1 cm below the upper cut (upper green part). Hue angle [($h^\circ = \tan^{-1}(b^*/a^*)$ when $a^* > 0$ or $h^\circ = 180 + \tan^{-1}(b^*/a^*)$ when $a^* < 0$] and chroma values [$C^* = (a^{*2} + b^{*2})^{1/2}$] were calculated from a^* and b^* values. L^* refers to the lightness, ranging from 0 = black to 100 = white; C^* represents color saturation, which varies from dull (low value) to vivid (high value); and h° is defined as an angle on a color wheel, with red-purple at 0°, yellow at 90°, bluish-green at 180°, and blue at 270°. In the results, $\Delta L^* = L^*_{\text{day }14} - L^*_{\text{day }0}$, $\Delta C^* = C^*_{\text{day }14} - C^*_{\text{day }0}$, and $\Delta h\circ = h^\circ_{\text{day}\,14} - h^\circ_{\text{day}\,0}$ are presented.

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