Postharvest Biology and Technology 117 (2016) 64–70

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

Effect of prestorage short-term Anoxia treatment and modified atmosphere packaging on the physical and chemical changes of green asparagus

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ARTICLE INFO

Article history:
Received 11 October 2015
Received in revised form 28 January 2016
Accepted 29 January 2016
Available online xxx

Keywords:
Asparagus
Anoxia
Modified atmosphere packaging
Pretreatment
Quality

ABSTRACT

The effects of prestorage short-term Anoxia treatment combined with modified atmosphere packaging (MAP) on quality changes during the storage of green asparagus (*Asparagus officinalis* L.) spears were investigated. Two sets of asparagus were used in this study. The first set underwent short-term Anoxia treatment via the administration of gaseous N_2 for 8 h at room temperature, while the second set was kept in ambient air at the same temperature. Consequently, treated and untreated spears were stored either freely or packaged in plastic bags with low density polyethylene, in which a passive modification of the atmosphere was allowed to develop. All samples were stored at 4 °C for 8 days, followed by 8 days at 10 °C. Samples treated with neither Anoxia nor MAP were used as a control. Our results show that treating the asparagus samples with Anoxia and MAP (Anoxia + PE) caused lower respiration, slowing the decrease in headspace O_2. In the Anoxia + PE treated samples, spears lost <12% fresh weight after 8 days at 10 °C. All treatments showed less increase in shear force while exposed at 4 °C for 8 days, as compared with the significant increase found when transferred to 10 °C. This increase in shear force was accompanied by the accumulation of fiber and lignin content. There was a positive relationship between toughening and fiber (R^2 = 0.958) and toughening and lignin (R^2 = 0.915). Moreover, the degradation of chlorophyll, sugar and ascorbic acid content under the Anoxia and MAP treatments were significantly reduced. The results of the present work indicate that Anoxia treatment, a non-chemical and simple postharvest technology, feasible for use in developing countries where food storage technologies are lacking.

1. Introduction

In recent years, asparagus (*Asparagus officinalis* L.) has been increasingly consumed due to its nutritional value and flavor. However, it is a perishable commodity with a short shelf-life after harvest due to its high respiration rate that rapidly leads to senescence (Hennion and Hartmann, 1990; Lill et al., 1990; Irving and Hurst, 1993). Issues arising from the loss of quality in asparagus after harvest include the shriveling of spears, toughening as a result of lignification of pericyclic fibers (Bhowmik et al., 2001), chlorophyll degradation (Albanese et al., 2007), and changes in organic acid and sugar content (Baxter and Waters, 1991; Bhowmik et al., 2000). The perishable nature of asparagus poses a challenge to the development of effective methods to extend its postharvest consumption. The above undesirable effects can be reduced by quick cooling upon harvesting, refrigeration (below 5 °C for long term storage), and storage in a modified atmosphere (Lipton, 1990).

The storage of asparagus by controlled or modified the atmosphere may prevent or lessen postharvest changes such as texture, flavor, color and chemical composition (McKenzie et al., 2004; Villanueva et al., 2005; An et al., 2006, 2007; Sothornvit and Kiatchanapaibul, 2009). This method involves removing O_2 and increasing the concentration of CO_2. Because vegetables are living organisms, they require optimal concentrations of O_2 and CO_2 for respiratory activity. Below a threshold of O_2 or above a threshold of CO_2, cells undergo anaerobic respiration and produce lactic acid, acetaldehyde and ethanol (Peppelenbos and Oosterhaven, 1998). The extent of anaerobic activity depends on the amount of time cells are exposed to air. Treating fresh produce with an anaerobic atmosphere or anoxic conditions using pure N_2 prior to storage slows the ripening of tomatoes (Kelly and Saltveit, 1988) and

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http://dx.doi.org/10.1016/j.postharvbio.2016.01.016
0925-5214/

avocados (Pesis et al., 1993), delays skin browning in litchi (Jiang et al., 2004), and reduces the decrease in the firmness of kiwifruit (Song et al., 2009). Torres-Penaranda and Saltveit (1994) reported that short-term Anoxia treatment of asparagus for up to 6 h benefited its quality retention.

Lill et al. (1990) reported that the rapid deterioration of stored asparagus was a major problem in retail display in supermarkets because stored spears had a shorter shelf-life after a simulated transit period. Bhowmik et al. (2000) indicated that the length of storage affected textural and compositional changes of asparagus after transfer in a simulation of retail sale. Although much research has focused on improving asparagus storage, few reports document the changes that usually occur during simulations of storage, transportation, and display in the supermarket.

Additionally, modified atmosphere packaging (MAP) techniques have been extensively described. MAP improves quality and extends the shelf-life of many types of fresh produce, including asparagus. However, very little information exists regarding the application of MAP in combination with pre-storage treatment of asparagus spears. The objective of the present work was to evaluate the effect of Anoxia treatment and/or MAP application on the quality of green asparagus. This work also focused on physical and chemical changes in different portions of spears (upper and lower portions) during storage at 4 °C and during an ensuing simulation of retail sale at 10 °C.

2. Materials and methods

2.1. Plant material and handling

Fresh green asparagus (*A. officinalis* L.) spears were obtained from commercial farms in the Nakhon Pathom province (Thailand) and transported to the laboratory. No damaged samples with closed bracts and 0.8–1.2 cm in diameter were selected. Spears were cut at 18 cm from the tip using a stainless steel knife. The asparagus was submerged in a 150 mg L^{-1} sodium hypochlorite solution for 2 min at 4 °C and briefly air dried with ambient air at 25 °C to remove surface liquid.

2.2. Sample treatments

Two different sets (12 kg per set) of asparagus were prepared. The first set was subjected to short-term Anoxia treatment with gaseous N_2. The asparagus was placed in a 10 L plastic chamber, then flushed with pure N_2. The O_2 concentration in the chamber was less than 0.05 kPa, as determined using a handheld Gas Analyzer (model: Oxybaby M + X, Germany). The samples were maintained in humidified N_2 for 8 h at room temperature (approximately 25 °C). The second set was kept in ambient air at the same temperature and 90–95% (Relative Humidity; RH) for 8 h. Consequently, both short-term Anoxia and ambient air treatments were established. N_2-treated or untreated spears were placed in polystyrene trays measuring 13 × 20 cm, then either left unpackaged or packaged in plastic bags with 40 μm low density polyethylene (LDPE, 15 × 22 cm dimension), in which a passive modification of the atmosphere was developed. The O_2 transmission rate was 187 mL m^{-2} h^{-1} at 23 °C and standard pressure (Well Plas Co., Ltd., Thailand). Each tray contained samples, with an average weight of 120 ± 5 g. One tray was performed for one replicate. All samples were refrigerated at 4 °C and 90–95% RH for 8 days and then moved to simulate display at 10 °C for 8 days. All analyses were performed at 0, 4 and 8 days of storage at 4 °C and at 4 and 8 days of storage at 10 °C, respectively. Each treatment was applied to four replicates in randomly of four trays.

2.3. Gas headspace analyses

The headspace gas concentrations in the sealed trays were measured in the same tray of each treatment at 0, 4 and 8 days of storage at 4 °C and at 4 and 8 days of storage at 10 °C. One milliliter of gas sample was withdrawn with a gastight syringe and then injected into gas chromatograph (Model GC-8A, Shimadzu, Japan) for measuring CO_2 and O_2. The injected gas sample was separated by a WG-100 column and analyzed with a thermal conductivity detector (TCD). Both gas concentrations were expressed in terms of partial pressure (kPa).

2.4. Weight loss

Weight loss was measured periodically by weighing samples on a digital balance (model PA2102, OHAUS Corporation, USA). Weights were recorded on day 0, 4 and 8 at 4 °C and day 4 and 8 at 10 °C. The results are reported as a percentage loss based on the initial weight of the same package.

2.5. Physical and chemical analysis

The asparagus spears, 0.8–1.2 cm in diameter and 18 cm in length and marked from the tip, were sectioned and separated into two cylindrical portions including the tip and the base at 9 cm intervals. The following determinations (physical and chemical changes) were made for each portion of the sample: texture, fiber, lignin, total chlorophyll, total sugar and total ascorbic acid.

2.5.1. Texture

Texture or toughening was determined by taking nine spears from each tray. The texture of each sample was measured at the middle point of each spear section by performing a cutting test with a texture analyzer (TA-XT plus, Stable Microsystems) a method which was modified from Rodríguez et al. (2004). Values are expressed as maximum shear force (*N*) using a single blade (7 × 12 cm) that cut each sample at a cross-head speed of 2.0 mm s^{-1} over 12 mm.

2.5.2. Fiber content

Fiber content was determined according to the AOAC (2000). Five grams of each fresh sample (tip and base) was individually heated in 25 mL of hot water and 6.25 mL of 50% (w/v) NaOH (Merck KGaA, Germany) for 5 min. The fiber was washed in running tap water through a size 30 mesh sieve containing the sample, then weighed to determine initial extracted weight. The extracts were dried at 100 °C for 2 h and weighed again to calculate the percentage of fiber content.

2.5.3. Lignin content

Lignin content was determined using the thioacidoglycolysis method, modified from Bruce and West (1989). Twenty-five grams of each fresh tissue (tip and base) was homogenized individually using 95% ethanol for 5 min then filtered using Whatman No. 4 filter paper under vacuum. The residue was washed with 17 mL of ethanol and dried at 50 °C for 24 h. Approximately 0.25 g of the dried residue was mixed with 7.5 mL of 2 N HCl (Merck KGaA, Germany) and 0.5 mL of thioglycolic acid (Carlo Erba Reagenti SpA., Italy), then boiled in a water bath for 4 h. The mixture was centrifuged at 7500 × *g* at 4 °C for 15 min. The residue (lignin thioglycolate) was washed with 10 mL of water, resuspended in 10 mL of 0.5 N NaOH for 18 h at room temperature and centrifuged. 2 mL of concentrated HCl was added to the supernatant. The lignin thioglycolic acid complex was precipitated at 4 °C for 4 h and centrifuged. The residue was then dissolved in 10 mL of 0.5 N NaOH. After performing appropriate dilutions, the absorbance was