Postharvest Biology and Technology 81 (2013) 51–59

Contents lists available at SciVerse ScienceDirect

Postharvest Biology and Technology

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

Ripening behavior and quality of modified atmosphere packed 'Doyenne du Comice' pears during cold storage and simulated transit

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ARTICLE INFO

Article history:
Received 14 May 2012
Accepted 18 February 2013

Keywords:
Pyrus communis L
Ethylene production
Ascorbic acid
Pear ripening
Pear quality
Physiological disorders

ABSTRACT

The effect of MAP on extending storage life and maintaining fruit quality was studied in 'Doyenne du Comice' (*Pyrus communis* L.) pears at Hood River and Medford, Oregon. Control fruit packed in standard perforated polyethylene liners started to show senescent core breakdown and lost the capacity to ripen at 20 °C after 4–5 months of cold storage in Hood River and after 5.25–6 months in Medford. LifeSpan® L257 MAP achieved steady-state atmospheres of 15.8% O_2 + 3.7% CO_2 in Hood River and 15.7–17.5% O_2 + 3.8–5.7% CO_2 in Medford. MAP inhibited ethylene production, ascorbic acid degradation and malondialdehyde accumulation, and extended storage life for up to 6 months with maintenance of fruit flesh firmness (FF) and skin color without commercially unacceptable level of physiological disorders. After 4, 5 and 6 months at −1 °C, MAP fruit exhibited climacteric-like patterns of ethylene production and softened to proper texture with desirable eating quality on day 5 during ripening at 20 °C. After 6 months at −1 °C plus 2 weeks of simulated transit conditions, MAP fruit maintained FF and skin color and had good eating quality at transit temperatures of 2 and 4.5 °C (10.1–11.5% O_2 + 4.8–5.2% CO_2), but reduced FF substantially and developed internal browning disorder at 7.5 and 20 °C (3.2–7.2% O_2 + 7.9–9.5% CO_2). The storage life of 'Doyenne du Comice' pears with high eating quality could be increased by up to 2 months when packed in MAP as compared with fruit packed in standard perforated polyethylene liners.

1. Introduction

One of the major goals of the Pacific Northwest (PNW) pear (*Pyrus communis* L.) industry is to increase per capita consumption by extending the marketing season and improving the eating quality of pears in the market. A desirable eating quality is defined as having a characteristic buttery-juicy fruit texture after ripening at temperatures of ~15–20 °C (Villalobos and Mitcham, 2008). To develop the buttery-juicy texture, pears need to have the capacity to produce ethylene at a sufficient rate to activate and complete the ripening process (Blankenship and Richardson, 1985). While winter pear cultivars generally require exposure to low temperatures or to ethylene gas after harvest in order to develop the capacity to ripen when subsequently held at warm temperatures (Villalobos and Mitcham, 2008), conditions at harvest and improper storage and handling can affect their ripening capacity and eating quality after long-term cold storage (Wang et al., 1985).

'Doyenne du Comice' ('Comice') is one of the three most important winter pear cultivars grown in the PNW of the United States (Sugar, 2007). 'Comice' is considered to be superior to most of the available pear cultivars for its excellent organoleptic quality. Based on practical experience, it is recommended that the optimum harvest maturity of 'Comice' pears grown in PNW is when the flesh firmness (FF) falls to between 57.8 N (13 lbf) and 48.9 N (11 lbf), the optimum storage temperature is −1.1 °C (30 °F), and the maximum storage period is typically between 120 and 130 d in conventional air at −1.1 °C (Sugar, 2007). To extend the marketing season, 'Comice' pears can be stored in either 1% O_2 + <0.1% CO_2 or 2% O_2 + 1% CO_2 for 3 months followed by holding in air at −1 °C for up to 3 additional months (Ma and Chen, 2003).

Modified atmosphere packaging (MAP) has potential for maintaining quality similar to controlled atmosphere (CA) storage but without the investment in infrastructure and instrumentation. 'Comice' pears grown in southern Oregon and packed in MAP (4% O_2 + 4% CO_2) maintained storage life for 4 to 5 months at −0.5 °C without disorders (Sugar, 2001). However, pears are known to be susceptible to CO_2 injury. Ma and Chen (2003) reported that 'Comice' pears developed unacceptable levels of internal browning (IB) disorder in atmospheres of 1% O_2 + <0.1% CO_2 and 2% O_2 + 1% CO_2 after 4 months at −1 °C. The effects of elevated transit temperatures on fruit quality and CO_2 injury also present a concern to the industry. Literature regarding the post-storage ripening behavior and eating quality of MAP packed 'Comice' pears grown in PNW is not available.

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http://dx.doi.org/10.1016/j.postharvbio.2013.02.010

The purpose of this study was to examine the effect of MAP on storage life, fruit quality, post-storage ripening behavior and eating quality of 'Comice' pears grown in the Hood River and Rogue River Valleys of Oregon. The effect of elevated temperatures during simulated post-storage transit on CO_2 injury (IB) and fruit softening of MAP packed fruit was also determined. The goal was to provide the pear industry with useful scientific information for extending the marketing season with high eating quality of this pear cultivar.

2. Materials and methods

2.1. Cold storage study

2.1.1. Fruit materials

At Hood River, Oregon (45.7°N, 121.5°W), forty ~10 kg boxes of commercially packed 'Comice' pears were obtained from a local packing company. The pears (referred as lot 1) were harvested from an orchard in Odell, Oregon on Sept. 28–29, 2011. The average initial fruit flesh firmness (FF) was 55.1 N ($N \times 0.2246$ = pounds). The fruit were washed and packed in LifeSpan® L257 MAP (Amcor, Victoria, Australia). The LifeSpan® L257 was designed for use in pears in ~10 kg cartons, with oxygen and carbon dioxide transmission rates of 2.6×10^{-7} and 5.5×10^{-7} L s^{-1} kPa^{-1}, respectively. The fruit temperature was reduced to 4.5 °C prior to MAP and further reduced to −1.1 °C using forced air cooling within 4–5 d after packing. The fruit were transported to the Mid-Columbia Agricultural Research and Extension Center (MCAREC), Hood River, Oregon and stored at −1.1 °C until assessment. Control fruit were packed in standard perforated polyethylene box liners. Four boxes were randomly selected for initial fruit parameter evaluations. Four boxes of each treatment were randomly selected for O_2 and CO_2, ethylene, and weight loss determinations during 6 months of storage. After 4, 5, and 6 months of storage, 4 boxes of each treatment were removed from cold storage, opened, and held at 20 °C. At day 0, ethylene production rate, FF, skin color, ascorbic acid content (AsA), and malondialdehyde content (MDA) were determined. Total soluble solids (TTS), titratable acidity (TA), extractable juice (EJ), organoleptic quality, and physiological disorders were determined after ripening at day 5.

At Medford, Oregon, in the Rogue River Valley (42.3°N, 122.8°W), 480 fruit were harvested from each of four orchard replicate blocks in a commercial orchard at an average FF of approximately 55.0 N on August 29, 2007 and September 2, 2008. The fruit were cooled in air at −0.5 °C for 7 d, then placed in boxes with either standard perforated polyethylene liners or LifeSpan® L257 MAP with 40 fruit per box and stored in air at −0.5 °C. Beginning approximately 5 months after harvest, the atmosphere of one box from each MAP and standard liner treatment replicate was sampled weekly for 6 weeks to determine the concentrations of O_2 and CO_2. One box of each replicate was then removed from storage and FF and fruit color were each determined on 10 fruit. The remaining 20 fruit per replicate were placed at 20 °C to ripen for 5–7 d for evaluation of eating quality and incidence of internal browning disorders.

2.1.2. Fruit weight loss

At Hood River, fruit of 4 boxes of each treatment were weighed every month during the 6 months of storage at −1.1 °C. The full box weight was used as an experimental unit. Cumulative weight loss was expressed as percentage loss of original weight.

2.1.3. Atmospheric determination

The concentrations of O_2 and CO_2 in LifeSpan L257 and standard perforated polyethylene liners were determined during storage using O_2 and CO_2 analyzers (Hood River: Model 900151, Bridge Analyzers Inc., Alameda, CA, USA; Medford: Food Package Analyzer Series 1400, Servomex, Crowborough, UK).

2.1.4. Ethylene production

Ethylene production rate was determined at Hood River using a flow-through system at 20 °C for 10 days. At each evaluation, 5 fruit per box were randomly selected, weighed, and transferred into a 10 L respiration chamber. Each chamber was sealed and supplied with constant humidified airflow (3.3 mL s^{-1}). One milliliter of the atmosphere was withdrawn with a syringe and injected into a gas chromatograph (Shimadzu GC-8AIF, Kyoto, Japan) equipped with a flame ionization detector and a Porapack Q column (80/100 mesh, 3.0 mm i.d., 2.0 m long). The carrier gas was nitrogen at a flow rate of 0.7 mL s^{-1}, the oven temperature was 90 °C, and the injector and detector temperatures were 140 °C. An external standard of ethylene (1.0 ppm) was used for calibration, as described by Chen and Mellenthin (1981).

2.1.5. Fruit FF and skin color

At each evaluation, 10 fruit were randomly selected from each box of LifeSpan L257 and standard liners for assessment of fruit skin color and FF. At Hood River, skin color was assessed visually and rated on a scale of 1–4, where 1 = green, 2 = green-yellow, 3 = yellow-green, and 4 = yellow (Elgar et al., 1997). At Medford, skin color was measured using a Minolta CR-200b portable tristimulus colorimeter recording in CIELAB colorspace coordinates (Hunter, 1975). Measurements were taken on the shaded side of each fruit, midway between the stem and calyx. FF at both locations was determined using a texture analyzer (Model GS-14, Guss Manufacturing Ltd., Strand, South Africa) with an 8 mm plunger that penetrated 9 mm in 0.9 s. Two measurements were obtained per fruit from opposite sides where ~16 mm diameter peel discs were removed.

2.1.6. AsA and MDA determinations

At Hood River, after determination of skin color and FF, fruit were peeled by a kitchen peeler and cut lengthwise. Four plugs were taken using a #4 cork borer from the cortex tissue just above the core from each fruit. Tissue plugs of five pears were sliced to 2 mm thickness with a razor blade and mixed at 2 °C.

L-ascorbic acid (AsA) was measured based on the methods of Cheng and Ma (2004) and Logan et al. (1998). Briefly, 5 g of cold fruit tissue was ground in 10 mL ice-cold 6% (v/v) $HClO_4$. The extract was centrifuged at 10,000 × *g* for 10 min at 2 °C and then the supernatant was used immediately for the measurement. A portion of the extract was neutralized with approximately one-third volume 1.5 M Na_2CO_3 to raise the pH to 1–2. 30–100 μL of the neutralized samples were used to assay the AsA spectrophotometrically (model Ultrospec 3100 pro, Biochrom Ltd., Cambridge, England) at 265 nm in 100 mM potassium phosphate buffer (pH 5.6), before and after 15 min incubation with 5 units AsA oxidase from *Cucurbita* (Sigma). The AsA content was determined from the absorbance difference and compared to a standard curve with the results expressed as mg kg^{-1} FW.

MDA concentration was measured according to Dhindsa et al. (1981). Two grams of cold tissue sample was ground and extracted in 5 mL 10% (w/v) trichloroacetic acid (TCA). After centrifugation at 10,000 × *g* for 15 min, a 2 mL aliquot of the supernatant was mixed with 2 mL 10% TCA containing 0.6% (w/v) thiobarbituric acid (TBA). The mixture was heated to 100 °C for 20 min, quickly cooled and centrifuged at 10,000 × *g* for 10 min. The supernatant was collected and absorbance was then measured at 450, 532, and 600 nm in a spectrophotometer (Ultrospec 3100 pro, Biochrom Ltd., Cambridge, England). The MDA concentration was calculated according to the formula: $6.45 \times (A_{532} - A_{600}) - 0.56 \times A_{450}$ and the results expressed as μmol kg^{-1} FW.