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Effect of ethylene and temperature conditioning on sensory attributes and chemical composition of 'Bartlett' pears

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ABSTRACT

'Bartlett' pears are resistant to ripening after harvest. Ethylene and temperature conditioning have been successfully used to stimulate fruit ripening with improved eating quality over non-conditioned fruit. However, few studies have evaluated the effect of different conditioning treatments on the sensory attributes of the fruit. In this study, we compared a descriptive sensory evaluation with the chemical composition of 'Bartlett' pears after the fruit were exposed to the following conditioning treatments: 2 d 100 $\mu l\,L^{-1}$ ethylene, 14 or 7 d at 0 °C, 7 or 3 d at 10 °C, or untreated control at 20 °C. Fruit were softened to 27, 18 and 9 N firmness before evaluation. At 9 N, fruit conditioned at 0 °C produced high levels of esters, and fruit conditioned at 0 °C for 14 d also were high in sweet taste and fruity flavor attributes. Fruit treated at 10 °C had lower concentrations of esters, but fruit treated at 10 °C for 3 d was high in sweet taste perception. Ethylene treated fruit produced low levels of esters and high levels of aldehydes and were associated with apple aroma, similar to the untreated control fruit. Water soluble pectin levels were highly and positively correlated with juiciness and sweetness and negatively correlated with firmness, crunchiness, and grittiness. Future studies should determine whether consumer liking of 'Bartlett' pear fruit is also influenced by conditioning treatment.

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1. Introduction

Fruit of most European pear (*Pyrus communis*) cultivars resist ripening after harvest (Villalobos-Acuna and Mitcham, 2008). Although 'Bartlett' pear fruit can slowly ripen immediately after harvest when held at room temperature (20 °C), they fail to achieve good color and acceptable texture and flavor (Puig et al., 1996). Pear fruit ripened on the tree or immediately after harvest do not develop a buttery and juicy texture which are both considered important parameters of good eating quality (Murayama et al., 1998). The reason for poor eating quality is low ethylene production by the fruit (Murayama et al., 1998), which may not be sufficient to induce the expression of genes that are critical for aroma volatile production and cell wall breakdown. As a result, fruit develop low concentrations of aroma compounds and a coarse, dry, and mealy texture (Gerasopoulos and Richardson, 1997). To alleviate this issue, several methods have been developed to stimulate pear ripening after harvest, including temperature conditioning (exposure to temperatures of 0–10 °C) and ethylene conditioning (Wang et al., 1972; Agar et al., 2000a; Miro et al., 2001; Villalobos-Acuna and Mitcham, 2008).

Partially ripe 'Bartlett' pears are preferred over unripe pears by consumers (Turner et al., 2005; Kupferman et al., 2010). Therefore, it is important to promote ripening to achieve good quality after harvest. For 'Bartlett' pears harvested at 76–84 N, cold storage at −1 to 0 °C for 14–21 d allowed the fruit to soften completely within 7 d at 20 °C (Mitcham et al., 2006). The time for conditioning was reduced to 3 or 2 d when 93 N fruit were stored at 5 or 10 °C, respectively (Agar et al., 2000b). The shortest conditioning time required occurred when the fruit were conditioned with ethylene gas. One to two days of exposure to 100 $\mu L\,L^{-1}$ ethylene at 20 °C was needed to stimulate ripening (Agar et al., 2000b). However, few studies have determined the influence of these various conditioning treatments on the sensory attributes, particularly taste and aroma, of pear fruit.

Texture, aroma and taste are important attributes related to the sensory quality of pears (Jaeger et al., 2003). With softening,

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pectin polyuronic acid materials become more water soluble, while the alcohol insoluble fractions and cell wall neutral sugars decrease (Ahmed and Labavitch, 1980; Murayama et al., 1998; Eccher Zerbini, 2002). Murayama et al. (1998) found that pear fruit that ripened to a dry and coarse texture had lower levels of water soluble polyuronides (WSP) than the fruit that ripened to a buttery and juicy texture. Puig et al. (1996) demonstrated that 'Bartlett' pears treated with 100 μL L^{-1} ethylene or low temperatures (0 °C for 4 weeks) after harvest ripened to yield a buttery and juicy texture; these treatments also had a high WSP content.

In addition to texture, aroma is a key component of pear fruit flavor (Jennings et al., 1964; Heinz and Jennings, 1966). In pears, the most prominent volatile compounds are esters of short to medium chain alcohols, especially ethyl and methyl esters (Paillard, 1990; Suwanagul and Richardson, 1998). Among the esters in 'Bartlett' pears, ethyl trans-2, cis-4 decadienoate has been defined as a 'character impact compound' (Jennings et al., 1964; Heinz and Jennings, 1966; Suwanagul, 1996; Komes and Gani, 2010), while hexyl acetate is a 'contributory flavor compound' (Jennings and Sevenants, 1964; Komes and Gani, 2010).

Sensory descriptive analysis is a powerful method to evaluate the sensory quality of fruit. It provides quantitative descriptions of products based on the perceptions of a trained panel (Stone and Sidel, 1993). Puig et al. (1996) used a trained panel to determine that 'Bartlett' pears treated with 100 μL L^{-1} ethylene after harvest or stored at 0 °C for 4 weeks could ripen in about 6 d with high sensory scores [buttery and juicy texture and flavor (acid/sugar balance and aroma)], while the fruit stored at 0 °C for 2 weeks or not treated with any cold storage or ethylene did not soften sufficiently in 7 d at 20 °C and had low sensory scores. Numerous studies have attempted to relate chemical composition to sensory attributes. Ideally, the instrumental measurements can then be used to predict related sensory properties effectively without performing sensory evaluation. Several studies have demonstrated good correlations between instrumental and sensory texture (Plocharski and Konopacka, 1999; Pitts et al., 2008; Chauvin et al., 2010); however, similar relationships between sensory attributes and volatile components have not been reported for pear.

The objectives of this study were to compare the effect of ethylene conditioning, or cold (0 °C) or intermediate (10 °C) temperature conditioning on the sensory attributes of 'Bartlett' pears, including aroma, texture, and taste, as evaluated by descriptive analysis. The relationship between sensory attributes and chemical composition, including volatile concentrations, cell wall polyuronide levels, SSC and TA, were also determined.

2. Materials and methods

2.1. Fruit source

Mature-green 'Bartlett' (*P. communis* L.) pears were harvested at the average firmness of 80 N from a commercial orchard in Sacramento, California early in the harvest season (July 19, 2010). The fruit were transported to the Postharvest Pilot Plant at the University of California, Davis on the same day, and visually sorted to eliminate defective fruit and to obtain fruit of uniform size (∼200 g) and green color for use in the experiments. The fruit were stored at 20 °C and >90% relative humidity prior to the initiation of treatments on the following day.

2.2. Treatments

The pears were randomly divided into six treatment groups with 210 fruit per treatment. Five treatment groups were exposed to different storage temperatures and times; 0 °C (low temperature) for 7 or 14 d, 10 °C (intermediate temperature) for 3 or 7 d, and 20 °C (control) for more than 11 d (until reaching the required firmness stages) with >90% relative humidity. The remaining group was treated at 20 °C with 100 μL L^{-1} ethylene gas in two 300 L stainless steel tanks for 48 h. Humidified air containing 100 μL L^{-1} ethylene was passed through the tank at 4 L min^{-1} to maintain carbon dioxide concentrations <0.3 kPa. After the initial treatments, all treatment groups were transferred to 20 °C for ripening until they softened to 9 N. Four single fruit replicates were chosen from each treatment group when the average fruit firmness reached 27, 18, and 9 N, and the firmness of the four fruit selected for instrumental and sensory evaluation were as close to 27, 18 or 9 N as possible. Portions of each individual fruit were used for analysis of skin color, firmness, cell wall polyuronides, volatile composition, SSC, TA, and sensory evaluation by a trained panel.

2.3. Ethylene concentrations

Ethylene concentration was measured every day or every other day on a subset of fruit from each treatment after fruit transfer to 20 °C and until the fruit began to senesce. Six fruit were placed into a 3.8 L jar as one replicate with three replicates for each treatment. The jars were sealed for 10–30 min before a 1 mL headspace gas sample was collected and analyzed for ethylene concentration using a gas chromatograph (AGC Series 400; Hach-Carle CO., USA) with a flame ionization detector (FID) and alumina column (Villalobos-Acuna et al., 2010).

2.4. Flesh firmness

Fruit firmness was determined at harvest (30 random fruit) and was measured every day or every other day (15 random fruit per treatment) after transfer to 20 °C for ripening until the fruit softened to 9 N ± 2.00 N (eating ripe, Mitcham and Mitchell, 2007). For analysis, the skin was removed from an area ∼20 mm in diameter on opposite sides of the equatorial region of each pear. Firmness was measured on each side of the pear using a Güss FTA Penetrometer (Güss, Strand, Western Cape, South Africa) fitted with an 8 mm probe (Villalobos-Acuna et al., 2010). The four fruit per replicate for each treatment and firmness stage were selected when the average firmness for each treatment reached 27, 18 or 9 N, and the firmness of the four fruit selected for instrumental and sensory evaluation were as close to 27, 18 or 9 N (±3.00 N) as possible.

2.5. Soluble solids content and titratable acidity

Two wedge-shaped slices were cut from stem to blossom end from opposite sides of each pear used for sensory evaluation and juiced for SSC and TA determination. A few drops of juice were used to measure SSC by refractometry (Reichert AR6 Series, Depew, NY) and 4 g of juice diluted in 20 mL deionized water were used for determination of TA (expressed as malic acid equivalents), using an automatic titrater (Radiometer TitraLab; Tim850 titration manager and SAC80 sample changer).

2.6. Sugar and acid contents

The same juice samples used for soluble solids and titratable acidity were also used to measure individual sugar and acid content. Fructose, sucrose, glucose, sorbitol, citric acid, and malic acid were quantified using an enzymatic procedure previously described for apple and tomato juices (Vermeir et al., 2007). Analysis was done using enzyme reagent kits (R-Biopharm, Marshall, MI), modified for use in 96-well microplates. The procedure followed kit instructions except that the volumes of water used to prepare the reagents were

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