Elevated Carbon Dioxide Storage of ‘Anjou’ Pears Using Purge-controlled Atmosphere

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Abstract. ‘Anjou’ pears (Pyrus communis L.) were placed in controlled-atmosphere (CA) storage immediately after harvest (<24 hours) or after a 10-day delay in refrigerated storage, and held there for 9 months at 1C. Oxygen in all atmospheres was 1.5% and CO₂ was at either 1% or 3%. Atmospheres in the flow-through system were computer-controlled at ±0.1%. After removal from CA storage, pears were evaluated immediately and after ripening at 21C for 8 days. Pears stored in 3% CO₂ were firmer, greener, and displayed less scald, internal breakdown, and stem-end decay than pears stored in 1% CO₂. In addition, no internal discoloration of ‘Anjou’ pears was evident when held with 3% CO₂. ‘Anjou’ pears held in 3%, CO₂ retained the ability to ripen after long-term storage. A 10-day delay in atmosphere establishment had little or no influence on the long-term keeping quality or ripening ability of ‘Anjou’ pears.

Materials and Methods

This study was conducted over 3 years using ‘Anjou’ pears grown in the Wenatchee, Wash., district. During the first year, eight boxes (four individual lots) were obtained from a commercial warehouse 1 day after harvest. Pears from three orchards with a known history of differences in storage quality were used in two of the years. Pears were divided into four groups. CA of 1.5% O₂ and 1% CO₂, or 1.5% O₂ and 3% CO₂ at 1C were established within 24 h after harvest on two groups. Identical CA regimes were established on the remaining two groups after 10 days in cold storage (1C). Pears were stored for 9 months before evaluation. All atmospheres were established at different times after harvest in a flow-through-type facility.

Received for publication 25 June 1993. Accepted for publication 2 Nov. 1993. I thank the Washington State Tree Fruit Research Commission for its financial support of this project. Use of a company or product name by the department does not imply approval or recommendation of the product to the exclusion of others that may also be suitable. The cost of publishing this paper was defrayed in part by the payment of page charges, under postal regulation 175.3144. Three values for external color were determined around the circumference of each fruit, and the average value for 10 fruit was reported. A model EP1 pressure tester (Lake City, Kelowna, B.C., Canada) equipped with a 7.8-mm head was used to determine firmness. Juice prepared from pear slices was titrated to pH 8.2 with 0.1 N NaOH and values were expressed as percentage of malic acid. SSC was determined with an Abbe-type refractometer calibrated at 20C. Carbohydrates were determined by the high-performance liquid chromatography method described by Bio-Rad (Bio-Rad, Richmond, Calif.). Disorders (CO₂ injury, scald, internal breakdown, cork spot, and stem decay) were evaluated by visual assessment and expressed as the percentage of fruit affected. Analysis of variance was determined by MSTAT (1988) as a factorial design. Based on significant F test, means were separated by Duncan’s multiple range test.

Results and Discussion

‘Anjou’ pears stored in 3% CO₂ were 41% firmer (15.6 N) than those stored in 1% CO₂, after 9 months of storage (Table 1). When

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Firmness (N)</th>
<th>SSC (% Brix)</th>
<th>TA (% malic)</th>
<th>SSC:TA ratio</th>
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</thead>
<tbody>
<tr>
<td>Atmosphere × ripening (days)</td>
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<tr>
<td>1.5% O₂ + 1% CO₂</td>
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<tr>
<td>0</td>
<td>37.8 b</td>
<td>13.0 ab</td>
<td>0.24 a</td>
<td>55 b</td>
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<td>8</td>
<td>19.1 c</td>
<td>12.5 c</td>
<td>0.21 c</td>
<td>61 a</td>
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<tr>
<td>1.5% O₂ + 3% CO₂</td>
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<tr>
<td>0</td>
<td>53.4 a</td>
<td>13.1 a</td>
<td>0.24 a</td>
<td>54 b</td>
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<tr>
<td>8</td>
<td>19.6 c</td>
<td>12.7 b</td>
<td>0.22 b</td>
<td>59 c</td>
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<td>Atmosphere × delay (days)</td>
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<td>1.5% O₂ + 1% CO₂</td>
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<td>26.2 b</td>
<td>12.8 b</td>
<td>0.22 b</td>
<td>58 a</td>
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<tr>
<td>10</td>
<td>30.2 b</td>
<td>12.8 b</td>
<td>0.22 b</td>
<td>58 a</td>
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<tr>
<td>1.5% O₂ + 3% CO₂</td>
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<td>36.0 a</td>
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<td>10</td>
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<td>13.1 a</td>
<td>0.22 b</td>
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</tbody>
</table>

1Pears were held at 21C for 8 days for ripening.
2Mean separation within columns and treatment groups by Duncan’s multiple range test (P ≤ 0.05).
3Atmosphere establishment delayed 10 days after harvest; pears were held at 1C during this period.

Additional index words. Pyrus communis, controlled-atmosphere storage
allowed to ripen for 8 days at ambient temperature, pears from either 1% or 3% CO<sub>2</sub> storage ripened to a similar firmness level (19 N). When CA was established immediately after harvest (<24 h), pears stored in 3% CO<sub>2</sub> were 37% firmer (9.8 N) than pears stored in 1% CO<sub>2</sub> (Table 1). When pears were in cold storage (1C) for 10 days before atmosphere establishment, the difference in firmness was 24% (7.2 N) in favor of pears that were stored in 3% rather than in 1% CO<sub>2</sub>. There was no difference in the SSC of 'Anjou' pears due to CO<sub>2</sub> concentration. There was a loss in SSC when pears were ripened for 8 days. Ripened pears from 3% CO<sub>2</sub> lost less SSC during ripening (3%) than pears from 1% CO<sub>2</sub> (4%) (Table 1). There was some difference (2%) in SSC of pears when CA establishment was delayed 10 days but only when stored in the 3%, CO<sub>2</sub> atmosphere (Table 1). Differences for individual carbohydrate concentrations (sucrose, fructose, glucose, and sorbitol) between pears from the two CO<sub>2</sub> atmospheres were minimal (data not shown). Neither CO<sub>2</sub> content of the atmosphere nor a 10-day delay in atmosphere establishment resulted in a change in the individual carbohydrate concentrations in 'Anjou' pears.

TA values were similar for pears stored in 1% or 3% CO<sub>2</sub>. When ripened for 8 days, 'Anjou' pears from the 3% CO<sub>2</sub> storage did not lose as much acid as pears from the 1% CO<sub>2</sub> storage environment (Table 1). A 10-day delay in CA establishment resulted in pears with similar acid values regardless of CO<sub>2</sub> level. Pears from the 3% CO<sub>2</sub> storage were higher initially in TA, or when CA was established in ≤24 h, but when CA establishment was delayed, TA content was identical (Table 1).

Pears from both CO<sub>2</sub> storage environments had similar SSC : TA ratios after ripening (Table 1). Those in 1% CO<sub>2</sub> had a higher SSC : TA ratio when atmosphere was established immediately, but the SSC : TA ratio was the same for the two CO<sub>2</sub> levels when atmosphere establishment was delayed 10 days (Table 1). 'Anjou' pears stored in 3% CO<sub>2</sub> were greener (higher hue value) than pears stored in 1% CO<sub>2</sub> at removal and after ripening (Table 2). Pears lost green pigment during ripening regardless of the CO<sub>2</sub> level in storage, but this loss in color was slightly greater with pears stored in 1% CO<sub>2</sub> than those stored in 3% CO<sub>2</sub>. This difference in color was also evident when Hunter “L” values were considered. Fruit from 3% CO<sub>2</sub> had a lower Hunter “L” value (indicative of a darker surface color than pears stored in 1% CO<sub>2</sub>), but no difference was present after 8 days of ripening.

p<sub>ears</sub> were held at 21°C for 8 days for ripening.

Hansen and Mellenthin (1962) and Claypool (1973) reported that high CO<sub>2</sub> in the storage atmosphere will result in a darker internal color of 'Anjou' pears. Internal color was not affected for pears stored in 3% CO<sub>2</sub> regardless of ripening time or delay in atmosphere establishment (Table 2). Internal Hunter “L” values were identical for pears from both CO<sub>2</sub> atmospheres before and after ripening, regardless of delay in CA establishment. Hunter “b” values or yellowness were also similar for all treatments. Internal hue values were not influenced by either ripening time or a delay for atmosphere establishment, but there was a change in pears from the different CO<sub>2</sub> atmospheres before ripening. This difference in hue values was slight (1.6 units) and was considered of no commercial consequence even though a change of 1.0 unit is visually detectable (Hunter and Harold, 1987).

Scald, internal breakdown, and stem decay (Table 3) were significantly reduced in 'Anjou' pears that were stored in 3% CO<sub>2</sub> when compared to 1% CO<sub>2</sub>. Internal breakdown (core browning) was of particular concern, but in this study pears had a lower incidence of the disorder in 3% CO<sub>2</sub> than in 1% CO<sub>2</sub>. Pears from one of the orchards used in this study have a history of internal breakdown and are poor candidates for CA storage, but reduced internal breakdown was also apparent when pears from this orchard were stored in 3% CO<sub>2</sub>.

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storage atmosphere is well above the recommended CO₂ atmosphere of 1% to 1.5% for ‘Anjou’ pears. In this study there were definite quality advantages for ‘Anjou’ pears stored at 3% CO₂ for 9 months relative to 1% CO₂ storage. These quality benefits include reductions in loss of firmness and greenness and disorders. A 10-day delay between harvest and atmosphere establishment had little or no influence on the long-term keeping quality or ripening ability of ‘Anjou’ pears.

**Literature Cited**


