Synchronizing Ripening in Individual 'Bartlett' Pears with Ethylene

Laura Puig¹, Diane M. Varga¹,
Paul M. Chen^{1,2}, and
Eugene A. Mielke¹

Additional index words. *Pyrus communis*, flesh firmness, extractable juice, dessert quality

Summary. 'Bartlett' pears (*Pyrus communis* L.) were harvested at commercial maturity (average flesh firmness of 18 lb), stored at 30F for 0, 2, or 4 weeks, and then placed into a ripening room at 68F with or without ethylene to evaluate ripening activities. Pears that were stored in air at 30F for <4 weeks did not ripen after 7 days at 68F in an ethylene-free (no-ethylene) room. These pears ripened normally and uniformly after 7 days at 68F in a room enriched with 100 ppm ethylene (yes-ethylene). 'Bartlett' pears that were stored in air at 30F for 4 weeks ripened normally after 5 days at 68F in the yes-ethylene room or 6 days at 68F in the no-ethylene room. The amount of cans produced per ton of fresh processed pears can be maximized most economically by exposing freshly harvested 'Bartlett' pears to 100 ppm ethylene at 68F for 7 days before canning.

About 70% (172,665 tons processed out of a total production of 250,032 tons in 1994) of 'Bartlett' pears is used commercially for canning in the Pacific Northwest (Newsletter of Washington-Oregon Canning Pear Asso-

ciation, 1994). The increase in overall pear production and limited fruit storage space in this region have forced the canning industry to process 'Bartlett' pears immediately after harvest. To maximize the number of cans obtained per lot of fresh pears (commercially termed case-yield), fruit within a lot must ripen at a uniform rate during storage at 68F before processing (practically called a ripening cycle). If fruit do not ripen uniformly during a ripening cycle, a low case-yield is expected. The term uniform ripening implies that each fruit softens to a similar flesh firmness, has a similar amount of extractable juice, and develops similar flavor during a ripening cycle. Recently, the canning industry has experienced low case-yield of 'Bartlett' pears that were processed immediately after harvest or after only a short period of cold storage, and this low case-yield has been attributed to nonuniform ripening (personal communication; Truit Bros, Salem, Ore.).

It generally is recognized that ethylene induces the ripening activities of many fruit crops. One of the most striking characteristics of climacteric fruit is their capability to exhibit autocatalytic ethylene production (i.e., ethylene stimulates its own synthesis) (Pech et al., 1994). In most winter pear varieties, a period of chilling at storage temperatures between 30 and 32F is required for inducing autocatalytic ethylene production (Pech et al., 1994). Low storage temperatures allow 1-aminocyclopropane-1-carboxylic acid (ACC, the immediate ethylene precursor) to accumulate and, as a consequence, fruit start to produce ethylene and ripen normally upon exposure to room temperature. In other types of fruit such as apple and kiwi fruit, low temperatures hasten the induction of ethylene-synthesizing competency and homogeneous ripening (Pech et al., 1994). Although the effect of low storage temperatures on 'Bartlett' pear ripening has not been studied, Porritt (1964) reported that 'Bartlett' fruit harvested at late maturity with flesh firmness of 16.7 lb required 10 days at 70F or 13 days at 60F to soften to 3 lb if they had not been exposed to prior low storage temperatures. Flesh firmness of 'Bartlett' pears at optimum commercial maturity is between 19 and 17 lb (Porritt, 1964). We frequently have observed that 'Bartlett' fruit harvested at optimum maturity

¹Mid-Columbia Agricultural Research and Extension Center, Oregon State University, 3005 Experiment Station Drive, Hood River, OR 97031-9512.

²To whom reprint requests should be addressed.

This research was support by funding from the Winter Pear Control Committee. Oregon State Agricultural Experimental Station technical paper no. 10,759. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked advertisement solely to indicate this fact.

do not ripen normally or they exhibit nonhomogeneous ripening at 68F if fruit have not been exposed to the low storage temperature at 30F or after <15 days of cold storage (personal observation). The time that elapses before a fruit starts to produce its own ethylene can be shortened by exposing the fruit to external ethylene. Earlier study showed that immature 'Bartlett' pears could be induced to ripen by exposing them to external ethylene (Hansen, 1967). By providing a constant flow of 200 ppm ethylene in a ripening room, 'Bartlett' fruit picked 6 and 3 weeks before commercial harvest reached the respiratory climacteric peaks on day 11 and 7, respectively, of the ripening period. In this study, we investigated the feasibility of commercially applying external ethylene to induce normal ripening and synchronize ripening of 'Bartlett' pears immediately after commercial harvest or after a short period of cold storage at 30F. The main goal is to create a practical ripening timetable, which will enable the cannery to maximize the case-yield of canned 'Bartlett' fruit early in the canning season.

'Bartlett' pears were harvested at commercial maturity (flesh firmness = 18 ± 0.5 lb) ($1 \text{ lb} = 4.448 \text{ N}$) from an orchard block at the Mid-Columbia Agricultural Research and Extension Center, Hood River, Ore., in 1994. Harvested fruit were transferred into 18 wooden boxes (44 lb/box) with polyethylene liners. Immediately after harvest, three boxes of fruit were placed into a ripening room enriched with ethylene at 100 ppm (± 20 ppm) (designated as the yes-ethylene room) and another three boxes were placed in a ripening room with no ethylene (<0.01 ppm C_2H_4) (designated as the no-ethylene room). The temperature and the relative humidity in both rooms were maintained at $68 \pm 1^\circ\text{F}$ and $75\% \pm 5\%$ respectively. The remaining 12 boxes of harvested fruit were placed into 30F storage for 2 or 4 weeks. After 1, 3, 5, or 7 days of exposure to 68F in the yes-ethylene or the no-ethylene room, 20 fruit from each box were removed to determine flesh firmness (FF) and extractable juice (EJ) according to Chen and Borgic (1985) and Chen and Mellenthin (1981). After 2 or 4 weeks of storage at 30F, three boxes of fruit samples were transferred into the yes-ethylene room and another three boxes were transferred into

Fig. 1. Changes in flesh firmness (FF) (softening pattern) of 'Bartlett' pears stored at 68F in a yes-ethylene (100 ± 20 ppm) (A) or no-ethylene (<0.01 ppm) (B) room for 7 days. Fruit were harvested on 15 Aug. 1994 with an average FF of 18 lb ($1 \text{ lb} = 4.448 \text{ N}$), stored in wooden boxes (44 lb/box) ($1 \text{ lb} = 0.454 \text{ kg}$) with polyethylene liners in air at 30F for 0 (AH), 2, and 4 weeks, and then stored in either the yes-ethylene room or the no-ethylene room at 68F.

the no-ethylene room at 68F. Fruit ripening indices were measured as described above.

After 6 days exposure to 68F in the yes-ethylene or no-ethylene room, texture and flavor (acid/sugar balance and aroma) of the ripened fruit were assessed by three trained panelists and rated on a 9-point hedonic scale, with 9 = buttery and juicy texture and excellent flavor and 1 = mealy, coarse, and dry texture and off flavor (McBride, 1986). Each panelist was given the same fruit samples that were selected at random from each replicate. Three fruit per replicate were assessed at each ripening interval. The procedures for the sensory evaluation of horticultural crops (Heintz and Kader, 1983) were adopted by the panelists. Before sensory evaluations, the fruit were chilled at 30F overnight and then warmed to 68F for 2 h. An average score of 5 or higher was arbitrarily defined as commercially acceptable.

After 5 or 7 days in the yes-ethylene or no-ethylene room, the frequency of individual fruit firmness was calculated to assess ripening uniformity. A total of 60 fruit (20 fruit per box) was

Fig. 2. Changes in extractable juice (EJ) of 'Bartlett' pears stored at 68F in a yes-ethylene (100 ± 20 ppm) (A) or no-ethylene (<0.01 ppm) (B) room for 7 days. Fruit were harvested on 15 Aug. 1994 with an average FF of 18 lb ($1 \text{ lb} = 4.448 \text{ N}$), stored in wooden boxes (44 lb/box) ($1 \text{ lb} = 0.454 \text{ kg}$) with polyethylene liners in air at 30F for 0 (AH), 2, and 4 weeks, and then stored in either the yes-ethylene room or the no-ethylene room at 68F.

used to calculate the frequency distribution of fruit firmness.

Fruits stored in the yes-ethylene room at 68F immediately after harvest without any prior 30F-storage softened to 4 lb on day 5 and to 2 lb on day 7 and had a concomitant reduction of EJ content (Figs. 1A and 2A). If these fruit were stored in the no-ethylene room at 68F, they softened very little and did not reduce in EJ content during 7 days of incubation (Figs. 1B and 2B). These results suggest that 'Bartlett' pears that are not exposed to 30F require an external exposure to ethylene to induce normal ripening. After 2 weeks of storage in air at 30F, the fruit stored in the yes-ethylene room at 68F softened to 3 lb after 5 days and to 2.5 lb after 7 days with concomitant reduction of their EJ content (Figs. 1A and 2A). On the other hand, fruit stored for 2 weeks at 30F and then stored in the no-ethylene room at 68F still had not softened sufficiently for commercial processing after 7 days (from 18 to 12 lb), and the EJ content in these fruit did not change (Figs. 1B and 2B). These results indicate that 2 weeks of chilling at 30F did

Fig. 3. Sensory evaluation of texture and flavor for ripened 'Bartlett' pears after 6 days of storage in a 68°F yes-ethylene (100 ppm $\pm$ 20 ppm) (A) or no-ethylene (<0.01 ppm) (B) room. The vertical line on each bar graph represent the standard error.

not induce ripening sufficiently after 7 days, and that an external ethylene treatment is required to induce a normal ripening process. After 4 weeks of storage in air at 30°F, 'Bartlett' fruit softened similarly in yes- or no-ethylene rooms to <4 lb on day 5 and to 2 lb on day 7 (Fig. 1 A and B). The desirable firmness of ripened 'Bartlett' pears for commercial canning process ranges between 2 and 4 lb with a 5/16-inch tip (personal communication, Truit Bros., Salem, Ore.). The amount of EJ in the fruit stored for 4 weeks at 30°F and then stored at 68°F with or without ethylene, however, changed differently during 7 days of 68°F storage. EJ in the fruit stored in yes-ethylene room decreased more dramatically (from 65 ml/100 g fresh weight on day 1 to 31 ml/100 g fresh weight on day 5 of ripening) than EJ in the fruit stored in no-ethylene room (from 65 ml/100 g fresh weight on day 1 to 51 ml/100 g fresh weight on day 5 of ripening) (Fig. 2 A and B). The changing pattern of EJ in the ripening pear fruit is an objective method for evaluating texture quality (Chen and Borgic, 1985). When pears are ripening normally, water-soluble polyuronides in the pulp tissues increase dramatically, resulting in an apparent increase in hydroscopic binding capacity of the

Fig. 4. Frequency of flesh firmness (lb) of 'Bartlett' fruit after 5 days (A) or 7 days (B) in a 68°F yes-ethylene (100 ppm ethylene) room without prior storage at 30°F.

Fig. 5. Frequency of flesh firmness (lb) of 'Bartlett' fruit after 5 days (A) or 7 days (B) in a 68°F yes-ethylene (100 ppm ethylene) room with 2 weeks of prior storage at 30°F.

speed centrifugal juicer (Chen and Borgic, 1985). The ripened pear fruit with buttery and juicy texture usually have a higher reduction of EJ than ripened pears with coarse and dry texture. On day 7 of ripening, EJ in the fruit from both treatments were reduced to the same level of about 31 ml (Fig. 2 A and B). If the fruit could soften normally with an apparent reduction of EJ to <40 ml/100 g fresh weight upon ripening, they developed good texture regardless of ethylene treatment (Fig. 3 A and B). Ripened fruit with good textural quality also developed good flavor (Fig. 3 A and B). These results indicate that 'Bartlett' fruit stored in air at 30°F for 4 weeks can ripen with good dessert quality after 5 days in a 68°F yes-ethylene room or after 7 days in a 68°F no-ethylene room.

The flesh firmness of pears that were not exposed to 30°F ranged from 3 to 6 lb after 5 days of storage at 68°F in the yes-ethylene room, indicating that the fruit did not ripen uniformly (Fig. 4A). However, these ethylene-treated fruit softened uniformly to between 2 and 3 lb (the proper firmness range for canning process) after 7 days of storage at 68°F (Fig. 4B). Therefore, storage for 7 days in a 68°F yes-ethylene ripening room is preferred for the cannery to maximize the case-

Fig. 6. Frequency of flesh firmness (lb) of 'Bartlett' fruit after 5 days (A) or 7 days (B) in a 68°F yes-ethylene (100ppm ethylene) room with 4 weeks of prior storage at 30°F.

Fig. 7. Frequency of flesh firmness (lb) of 'Bartlett' fruit after 5 days (A) or 7 days (B) in a 68F no-ethylene (<0.01 ppm ethylene) room with 4 weeks of prior storage at 30F.

yield of the fruit lots processed immediately after harvest. The flesh firmness of pears stored for 2 weeks at 30F plus 5 days at 68F in a yes-ethylene room was between 2.5 and 4.5 lb (Fig. 5A). Since 4 lb firmness is the standard for canning, about 10% of these fruit was still too firm (4 to 4.9 lb) to meet the canning standard. After 7 days storage in the yes-ethylene room at 68F, pear flesh firmness was 2 to 3 lb (Fig. 5B). These results indicate that storage at 68F for 7 days in the yes-ethylene room was also necessary to maximize the case-yield of the fruit to be processed after 2 weeks of cold storage. After 4 weeks of 30F storage, fruit stored in the 68F yes-ethylene room for 5 days softened uniformly to between 2 and 3.5 lb (Fig. 6A). After 7 days in the 68F yes-ethylene room, about 28% of these fruit had a FF of 1.5 to 1.9 lb (Fig. 6B) and were probably too soft to be processed. Therefore, a 5-day storage in the yes-ethylene room at 68F would be preferred for canning 'Bartlett' fruit that had been stored for 4 weeks at 30F. Fruit stored for 4 weeks at 30F and then stored at 68F for 5 days in a no-ethylene room softened to 2 to 5.5 lb (Fig. 7A). These fruit were not suitable for canning because they softened rather unevenly. After 7 days in the 68F no-ethylene

room, fruit softened uniformly to 1.5 to 2.5 lb (Fig. 7B). Again, 18% of ripened fruit softened to <2 lb and would be overripe for canning. Perhaps a 6-day storage in the 68F no-ethylene room might be preferred for fruit that have been stored previously for 4 weeks at 30F.

Since 'Bartlett' fruit in this study could ripen normally in the no-ethylene room when the fruit had been stored in air at 30F for 4 weeks, we did not pursue further experiments with fruit stored for 5 weeks or longer at 30F, assuming that ripening would be adequate for canning.

In conclusion, we propose the following recommendations for ripening 'Bartlett' pears to maximize the case-yield for commercial canning process.

- 1) Fruit without previous exposure to storage temperature at 30F or that have been stored at 30F for < 3 weeks should be ripened in a 68F-room enriched with 100 ppm ethylene for 7 days.
- 2) Fruit that have been stored at 30F for 3 to 4 weeks should be ripened in a 68 F-room enriched with 100 ppm ethylene for 5 days or in a 68F no-ethylene room for 6 days.
- 3) Fruit that have been stored at 30F for longer than 4 weeks should be handled with the normal commercial canning process.

Literature Cited

- Chen, P.M. and W.M. Mellenthin. 1981. Effects of harvest date on ripening capacity and postharvest life of 'd'Anjou' pears. J. Amer. Soc. Hort. Sci. 106:38-42.
- Chen, P.M. and D.M. Borgic. 1985. Changes in water soluble polyuronides in the pulp tissue of ripening 'Bose' pears following cold storage in air or in 1% oxygen. J. Amer. Soc. Hort. Sci. 110:667-671.
- Hansen, E. 1967. Ethylene-stimulated metabolism of immature 'Bartlett' pears. Proc. Amer. Soc. Hort. Sci. 91:863-867.
- Heintz, C.M. and A.A. Kader. 1983. Procedures for the sensory evaluation of horticultural crops. HortScience 18:18-22.
- McBride, R.L. 1986. Hedonic rating of food: Single or side-by-side sample presentation? J. of Food Tech. 21:355-363.
- Pech, J., C. Balagur, A. Latche, and M. Bouzayen. 1994. Postharvest physiology of climacteric fruits: recent developments in the biosynthesis and action of ethylene. Sci. Des Aliment 14:3-15.
- Porritt, S. W. 1964. The effect of temperature on postharvest physiology and storage life of pears. Can. J. Plant Sci. 44:568-579.