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Short Communication

Internal Ethylene Levels during Ripening and Climacteric in Anjou Pears[1]

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Previous investigations have shown that ripening of Anjou pears (*Pyrus communis* L.) was initiated by applied ethylene separately and independently of the respiratory climacteric (12). Softening occurred prior to or without the development of the climacteric (14). It has been reported that a critical triggering concentration of ethylene is required to produce a response (3). A small peak of ethylene production was related to the initiation of softening and a larger increase associated with the climacteric (14). However, analysis of the ethylene evolution alone does not provide an adequate test for the physiologically active concentration of ethylene dissolved or adsorbed within the tissue (7). Therefore, the status of internal ethylene in Anjou pears during ripening and climacteric needs to be determined. This study was undertaken to determine if a lower level of endogenous ethylene is required for softening than for the respiration climacteric.

Unlike cantaloupe (7) or honeydew melons (9), Anjou pears do not have a central cavity from which the direct measurement of the ethylene concentration in the internal atmosphere can be made. Although a 1-ml sample of air has been obtained from the core of a pear for the measurement of internal CO_2 and O_2 (15), a larger sample is required to detect minute amounts of ethylene present. While several methods (1, 2, 11) have been described for extracting internal ethylene from plant tissues where gas samples cannot be readily obtained with a syringe, the procedure described by Blanpied (2) was followed in this experiment using a vacuum of 36 mm. Beyer and Morgan (1) reported that using a vacuum below 100 mm Hg may induce the release of bound or dissolved ethylene from plant tissues. Therefore, the absolute values of internal ethylene may vary as different amounts of vacuum are applied in the extraction procedure. The main objective of this experiment was to compare the relative ethylene levels during the initiation of softening and onset of climacteric.

In order to avoid the wounding effect (8) on ethylene synthesis, whole fruits rather than slices were used. Since the opening of a 4-liter suction flask described by Blanpied was too small for a mature pear, a 250-mm desiccator with tubulated cover was used. Sampling techniques for ethylene analysis, respiration, and fruit firmness have been described previously (14).

Anjou pears do not ripen evenly without exposure to either ethylene or cold storage treatment (6). Fruits in this experiment were picked at desired maturities (85% and 100% based on a postbloom period of 147 days) and stored at −1.1 C for 60 days prior to ripening at 20 C. No exogenous ethylene was applied in order to establish the endogenous level in the natural ripening process.

The internal concentration of ethylene was 0.12 μl/l (Fig. 1A) in 85% mature fruit on the first day following removal from cold storage. Ethylene then decreased to 0.02 μl/l and continued at this level until the 7th day when ethylene increased 4-fold to 0.08 μl/l. This increased amount of ethylene must have induced synthesis of the enzyme system which was responsible for the initiation of softening. Once the softening mechanism was created, the decrease in firmness continued even though the ethylene declined below the level at which induction occurred. Softening began 3 days after the rise of ethylene. This delay may be due to the fact that the specific enzyme synthesis was triggered by ethylene when the concentration exceeded the threshold level for softening, but some time transpired before softening could be measured. Pratt and Goeschl (9, 10) suggested that probably other steps intervene between the ethylene action and the change in ripening reactions. They also envisaged that a variety of responses in the fruit may be triggered by ethylene and proceed more or less independently of one another; also, ethylene requirements may be different for various ripening reactions. No climacteric rise in respiration was evident in the 85% mature fruit during the 14-day period.

In fully mature fruit, the internal ethylene concentration was 0.94 μl/l (Fig. 1B) following cold storage treatment. Although the level of ethylene subsequently dropped, it remained above the induction level for fruit softening. As the ethylene then increased to 0.46 μl/l, the climacteric developed. Accompanying the climacteric, internal ethylene increased rapidly and reached a peak at 40.66 μl/l in 11 days. Apparently, the mechanism which initiates the climacteric rise in respiration has to be activated by a much higher level of ethylene. The continuous stimulation by this higher concentration of ethylene appears to be necessary to complete the climacteric pattern.

Our previous work (14) showed that the climacteric rise can be initiated by 14 days' treatment with 1 μl/l ethylene in 57% mature Anjou pears, or 15 days' treatment with 0.5 μl/l ethylene in 71% mature fruits, or 17 days' treatment with 0.2 μl/l ethylene in 86% mature fruits but occurs naturally in fully mature fruits. This suggests that maturation involves an increase in sensitivity to ethylene and in the development of the ripening mechanism. It also indicates that the failure of developing a climacteric in the 85% mature fruit used in this experiment was not due to the inability of the fruit to respond but to the lack of sufficient quantities of ethylene.

Cold temperature apparently has a stimulative effect on ethylene biosynthesis in the pear (6, 13). The initial high levels

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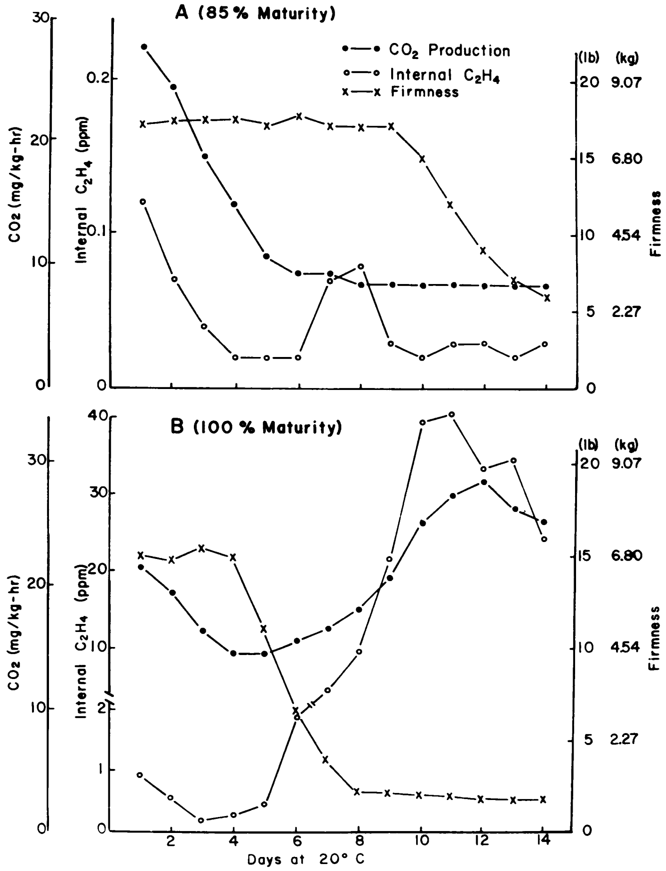

FIG. 1. Respiration, internal ethylene, and firmness in Anjou pears at two stages of maturity after 60 days of storage at −1.1 C.

of internal ethylene in 85% and 100% mature fruits were due solely to the effect of cold storage treatment. Similar reaction to the cold storage treatment was found in 71% mature fruits (unpublished data). However, the fruit failed to soften due to lack of a spontaneous rise of ethylene as occurred in the 85% mature fruit.

Burg and Burg (4) estimated the threshold concentration required to initiate fruit ripening is between 0.04 and 0.5 μl/l. However, Dennis *et al.* (5) found that more than 3 μl/l of ethylene was necessary for ripening of tomatoes. Our data suggest that 0.08 μl/l was required for initiation of softening in Anjou pears but the climacteric was not initiated until ethylene increased to 0.46 μl/l. Ethylene appears to act initially as a triggering agent for softening mechanism, but a higher physiologically active level is required throughout the climacteric phenomenon.

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