

# Ethylene Absorbent to Maintain Quality of Lightly Processed Fruits and Vegetables

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## ABSTRACT

Ethylene had an undesirable effect on the quality of kiwifruits, bananas, broccoli, and spinach leaves that were prepared and stored as lightly processed products. A 2 or 20 ppm ethylene treatment hastened the softening of the pulp of kiwifruits and bananas held at 20°C. Use of charcoal with palladium chloride, as ethylene absorbent, prevented the accumulation of the ethylene and was effective in reducing the rate of softening in kiwifruits and bananas and of chlorophyll loss in spinach leaves, but not in broccoli.

Key Words: kiwifruit, bananas, broccoli, spinach, ethylene, lightly-processed

## INTRODUCTION

QUALITY of lightly processed fruit and vegetable products during handling and storage is maintained by utilizing or modifying practices recommended for fresh produce. Research studies have shown benefits of vacuum cooling (Friedman, 1951), low temperature (Pripke et al., 1976, Bolin et al., 1977, Sugawara et al., 1987), and modified atmospheres (Wolfe and Robe, 1980) for prepackaged spinach, cole slaw, shredded lettuce or mixed salad. Use of washing or chemical treatments to remove exposed cellular components or specific cutting tools to minimize damage has been helpful for shredded lettuce (Bolin et al., 1977; Krahn, 1977, Ohta and Sugawara, 1987).

These practices do not remove ethylene ( $C_2H_4$ ), a natural ripening initiator that is produced by fruits and vegetables.  $C_2H_4$  is used commercially to ripen climacteric fruits, such as bananas, tomatoes, honeydew melons, and avocados. Since it induces loss of green color (chlorosis), abscission, and softening, commercial storage rooms should have equipment to remove  $C_2H_4$  when potential problems exist (Watada, 1986).

$C_2H_4$  production can be induced or stimulated when plant tissues are injured (Hoffman and Yang, 1982; McGlasson, 1969), so  $C_2H_4$  production might be expected when fruits and vegetables are peeled, sliced, and cut for preparation as lightly processed products. As these products are placed in sealed packages,  $C_2H_4$  can accumulate and cause undesirable quality changes. We determined the effects of  $C_2H_4$  as well as of an  $C_2H_4$  absorbent on the physiology and quality of kiwifruits, bananas, broccoli, and spinach leaves that were prepared as lightly processed products and stored in trays. Factors monitored were firmness, chlorophyll content,  $CO_2$  and  $C_2H_4$  concentrations, and soluble free amino acids content.

## MATERIALS & METHODS

KIWIFRUIT, obtained from a local distribution center, were peeled and sliced to 1.1 cm thickness. Bananas at the green tip stage, obtained from a local supermarket, were cut into 4 cm length sections. Five slices of kiwifruit and five sections of banana were placed to-

gether in a metal tray with a glass cover at 20°C with air, or air + 2 or 20 ppm  $C_2H_4$  flowing through the closed tray at 100mL/min. Each treatment was replicated 3× and samples were removed after 0, 1, 2, or 3 days storage for firmness measurements.

The effects of charcoal with palladium chloride to remove  $C_2H_4$  were determined with kiwifruits, bananas, broccoli, and spinach leaves. Broccoli from the supermarket was chopped into small pieces. Spinach from the supermarket was hand-torn into small pieces. Six kiwifruit slices and four sections of banana or 60 g of broccoli pieces and 40 g of spinach pieces were placed in a metal tray with a glass cover at 20°C with or without 10g of paper packets containing  $C_2H_4$  absorbent. Each treatment was replicated 3× and samples were removed after 0, 1, 2, or 3 days storage for determination of chlorophyll and total free amino acids contents in spinach and broccoli tissues and firmness of kiwifruit and banana tissues.  $CO_2$  and  $C_2H_4$  concentrations in each tray were monitored daily.

Firmness was determined with an Instron Model TM by measuring the force required to press a 4 mm × 16 mm flat probe 3 mm into the pulp or core of 1.1 cm thick sliced kiwifruit, or a 4.4 cm diameter round flat probe 5 mm into 1.1 cm thick slice of banana. A single measurement of core tissue and duplicate measurements of pulp tissue were made on each kiwifruit slice. With banana, measurements were made on two slices from each section. Chlorophyll was extracted from spinach leaves or broccoli florets with 80% cold acetone and absorbance of the extract measured at 645 and 663 nm (Arnon, 1949). Free

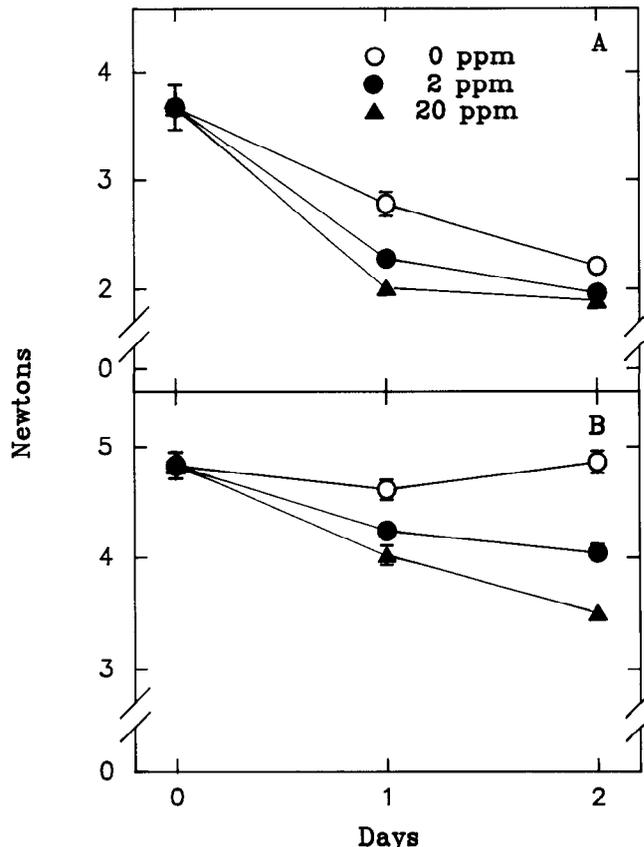


Fig. 1—Firmness of (A) pulp of kiwifruit slices and (B) banana sections held in air with ethylene at 20°C.

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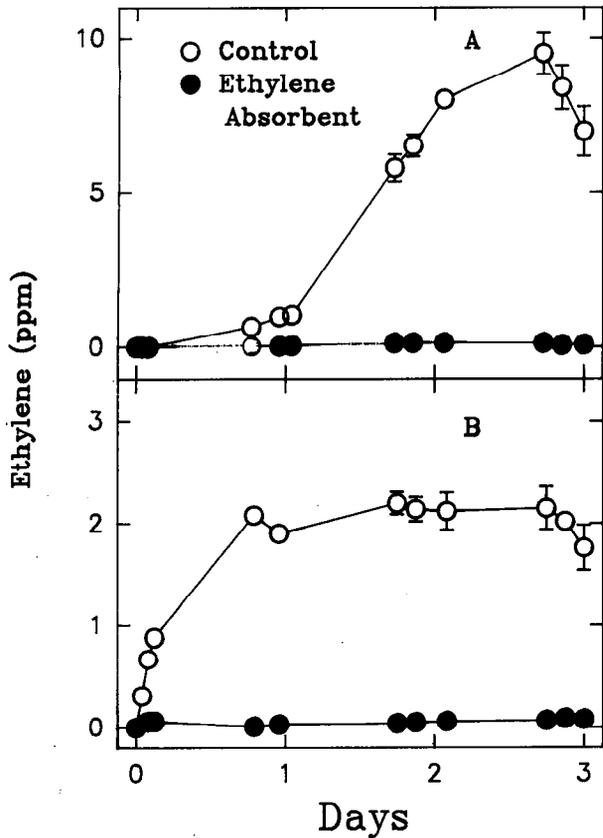


Fig. 2—Ethylene concentration in trays with or without ethylene absorbent (Charcoal with palladium chloride) containing (A) kiwifruit slices and (B) banana sections held at 20°C.

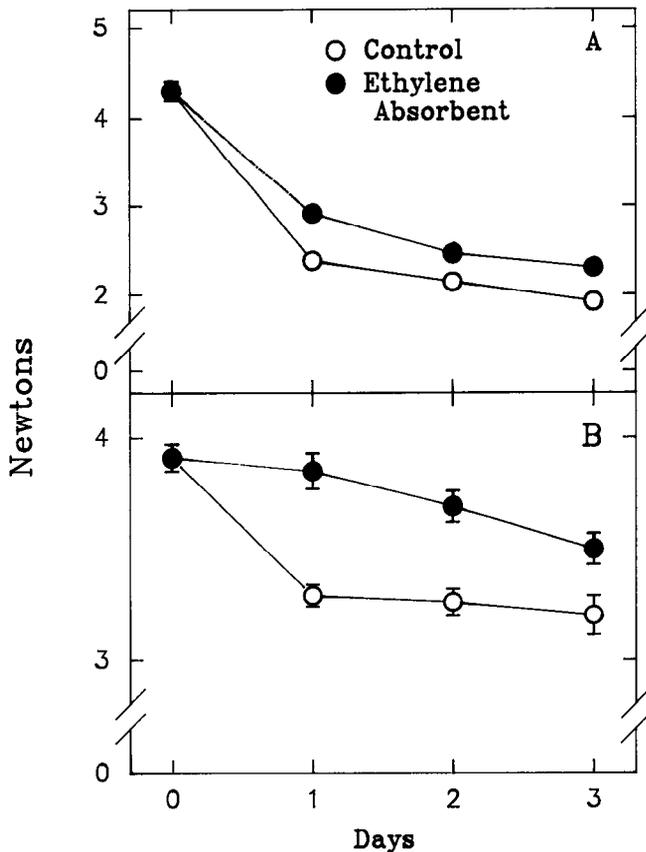


Fig. 3—Firmness of (A) pulp of kiwifruit slices and (B) banana sections stored with or without ethylene absorbent (Charcoal with palladium chloride) and held at 20°C.

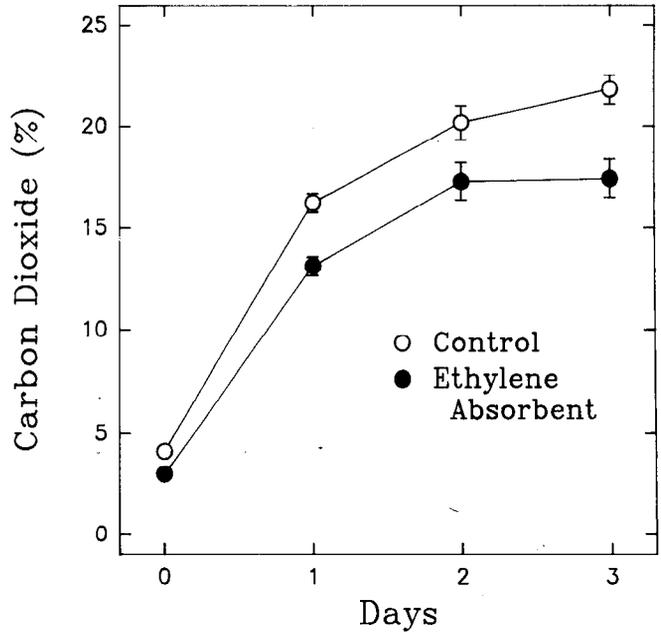


Fig. 4—Carbon dioxide concentration in kiwifruit slices and banana sections trays with and without ethylene absorbent. Trays held at 20°C.

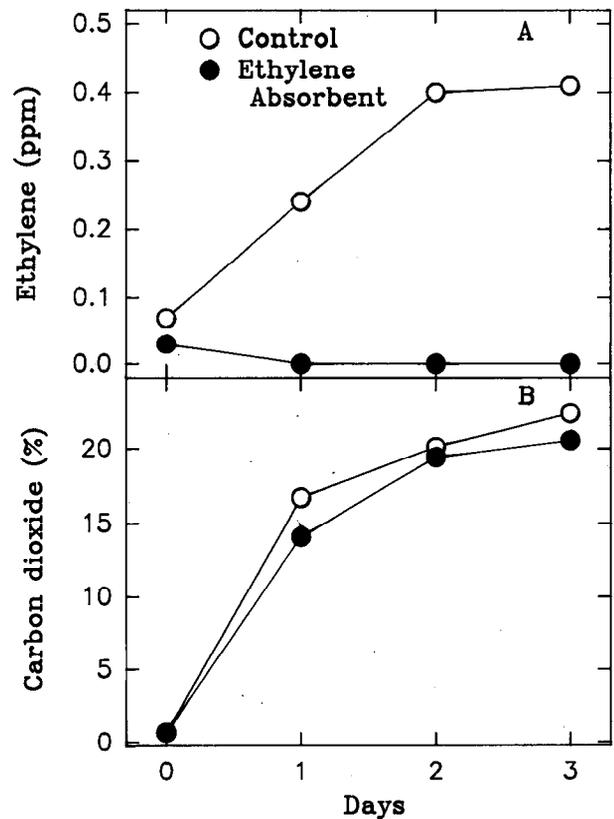


Fig. 5—(A) Ethylene and (B) carbon dioxide contents in broccoli and spinach trays with or without ethylene absorbent stored at 20°C.

amino acids were extracted from spinach leaves or broccoli with hot 80% ethanol, reacted with ninhydrin and hydrindantin in sodium acetate buffer, and absorbance of the reaction product measured at 570 nm (Moore and Stein, 1954). CO<sub>2</sub> and C<sub>2</sub>H<sub>4</sub> contents were measured with TCD and FID gas chromatography, respectively.

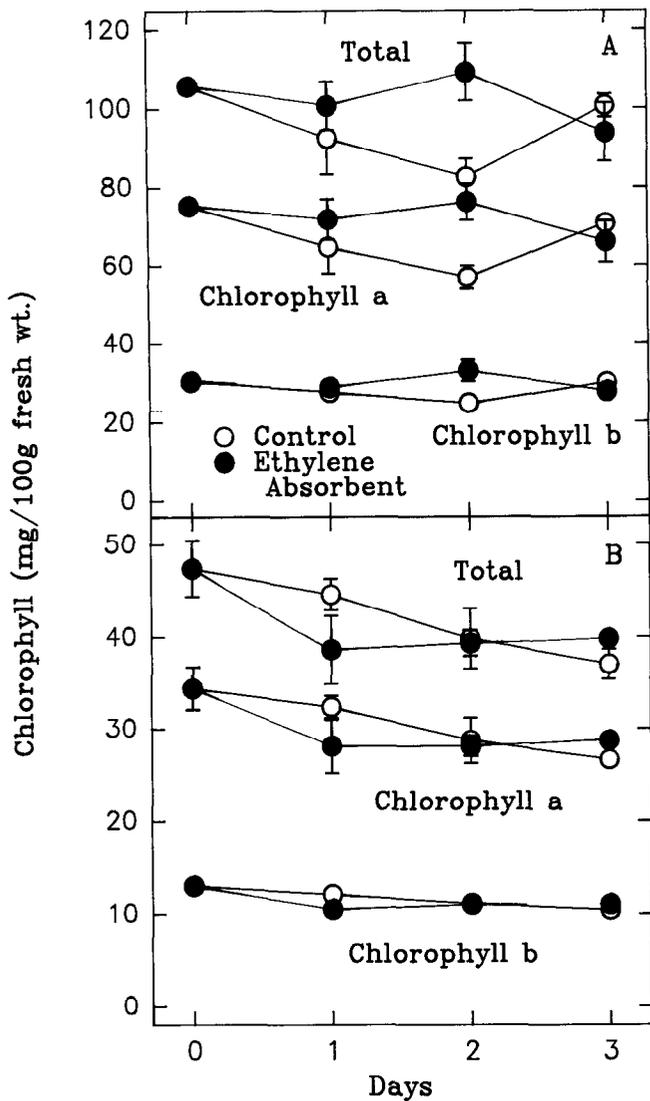


Fig. 6—Chlorophyll content of (A) spinach pieces or (B) broccoli pieces stored with or without ethylene absorbent and held at 20°C.

## RESULTS & DISCUSSION

THE RATE of softening of sliced kiwifruit pulp and banana sections was enhanced by the 2 or 20 ppm  $C_2H_4$  treatment (Fig. 1). After 1 day at 20°C in air + 2 or 20 ppm  $C_2H_4$ , firmness of the kiwifruit pulp decreased by 50%, down to 2 newtons. Firmness of fruit held in air decreased to that level after 2 days storage. Firmness of core tissue was not affected by the  $C_2H_4$  treatment (data not presented). Average firmness of sliced bananas, which initially was about 5 newtons, decreased to 4 and 3.5 newtons with 2 and 20 ppm  $C_2H_4$ , respectively, after 2 days storage. Firmness of banana held in air changed minimally during the 3 day period.

Charcoal with palladium chloride was effective in absorbing most of the endogenously produced  $C_2H_4$  during the 3 days storage (Fig. 2). Without the absorbent,  $C_2H_4$  content in the kiwifruit tray had a higher concentration of  $C_2H_4$  than the banana tray. The higher level was due in part to the greater  $C_2H_4$  production by intact kiwifruit than banana fruit and also due to greater cut surface area by the kiwifruit. That is, kiwifruit fruit slices were thin and peeled, whereas the bananas sections were thick and not peeled.

Softening rates of kiwifruits and bananas were affected by the  $C_2H_4$  absorbent (Fig. 3). Firmness of kiwifruit pulp, which initially was about 4.3 newtons, decreased more rapidly with-

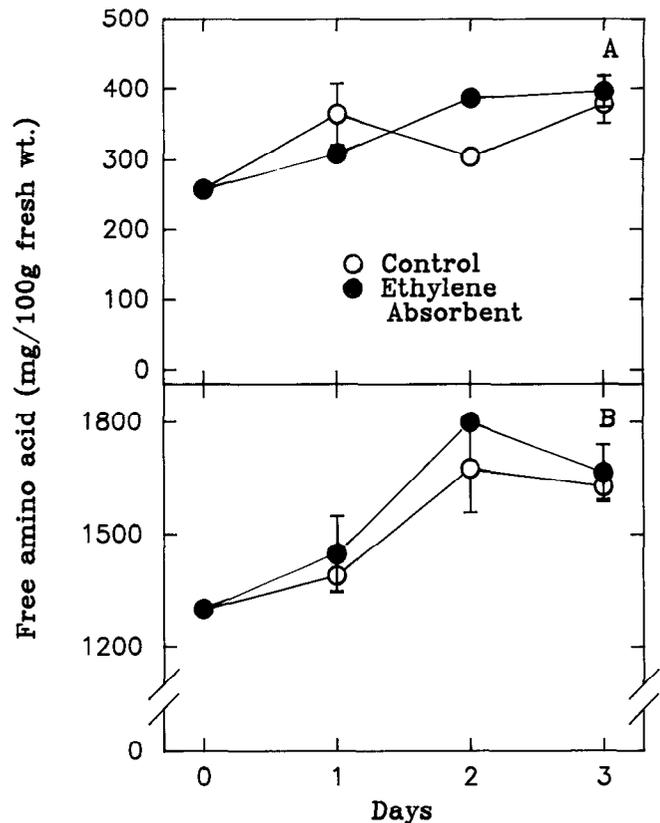


Fig. 7—Free amino acids content of (A) spinach pieces or (B) broccoli pieces stored with or without ethylene absorbent and held at 20°C.

out the absorbent than with the absorbent within the first day. Thereafter, rates of softening of both were similar. Firmness of core tissue decreased from about 11 newtons to 5.5 newtons and the rates of decrease of tissue with and without absorbent were similar (data not presented). Bananas without the absorbent softened to a minimum level of about 3.3 newtons by day 1, whereas those with the absorbent softened more slowly to about 3.5 newtons by day 3.

$CO_2$  accumulated faster in trays without the absorbent than with the absorbent, which probably was due to the  $C_2H_4$  stimulated respiration by the kiwifruits and bananas. (Fig. 4). The 15 to 20%  $CO_2$  level noted in those trays were levels which have been reported to cause injury (Kader, 1986), but no injury was noted, perhaps because of the short holding period.  $CO_2$  has an inhibitory effect on ethylene-induced softening and ripening (Palmer, 1971; Arpaia et al., 1985; Rosen and Kader, 1989).

$C_2H_4$  in the broccoli and spinach trays had accumulated to about 0.4 ppm, which was effectively absorbed by charcoal with palladium chloride (Fig. 5). Degradation of chlorophyll a was minimized by the reduced level of  $C_2H_4$  in spinach but not in broccoli (Fig 6). In broccoli, degradation of chlorophyll a and b was not affected by the reduced  $C_2H_4$  level, as noted also with chlorophyll b of spinach. Lack of response in broccoli may have been due to its morphological characteristic, that is, broccoli as a floret, does not contain as much active chlorophyll as spinach leaves.

The  $CO_2$  content in broccoli and spinach trays accumulated to about 15% after 1 day and about 20% after 2 days storage (Fig. 5).  $CO_2$ , at that high level, probably delayed chlorophyll degradation, as noted with broccoli by Toivonen et al. (1982), and consequently may have masked the maximum effect of the absorbent on chlorophyll degradation and free amino acid changes.

Free amino acids had accumulated in both spinach and broc-

coli and accumulation was not affected by ethylene removal (Fig. 7). Since amino acids accumulate with degradation of proteins during senescence, more accumulation was anticipated in tissues where senescence was hastened by C<sub>2</sub>H<sub>4</sub>. The time period probably was not sufficient for metabolism to deteriorate with increased senescence.

### CONCLUSIONS

C<sub>2</sub>H<sub>4</sub> PRODUCTION was stimulated by the physical actions of light processing, and the amount of production was sufficient, even with the vegetables, to have an effect on plant physiology and quality. Removal of C<sub>2</sub>H<sub>4</sub> with an absorbent, (charcoal with palladium chloride was very effective) is beneficial for maintaining the quality of lightly processed products.

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### C BOTULINUM IN MENHADEN SURIMI. . . From page 1563

means internal temperatures held for specified times, then currently reported surimi time/temperature processing conditions adequately provide a margin of safety with regard to *C. botulinum* type E.

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