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 (Priepke 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

KIWIFRUITS, 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 together 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

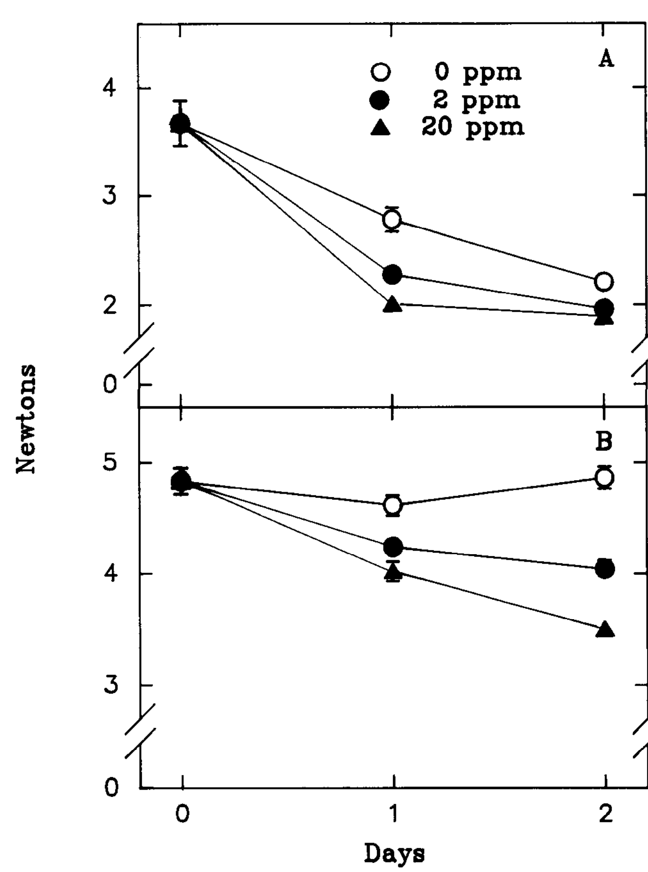

Fig. 1—Firmness of (A) pulp of kiwifruit slices and (B) banana sections held in air with ethylene at 20°C.

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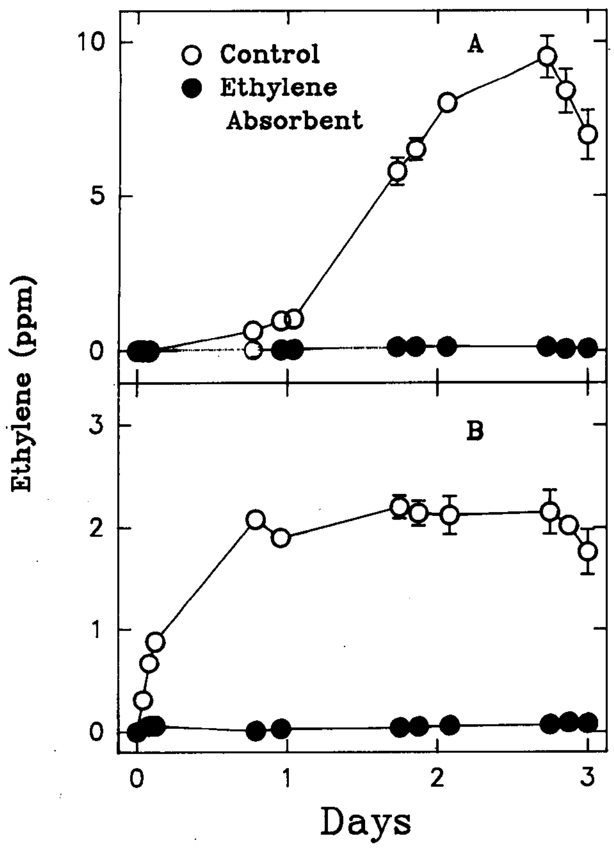

Fig. 2—Ethylene concentration in trays with or without ethylene absorbent (Charcoal with palladium chloride) containing (A) kiwifruit slices and (B) banana sections held at 20°C.

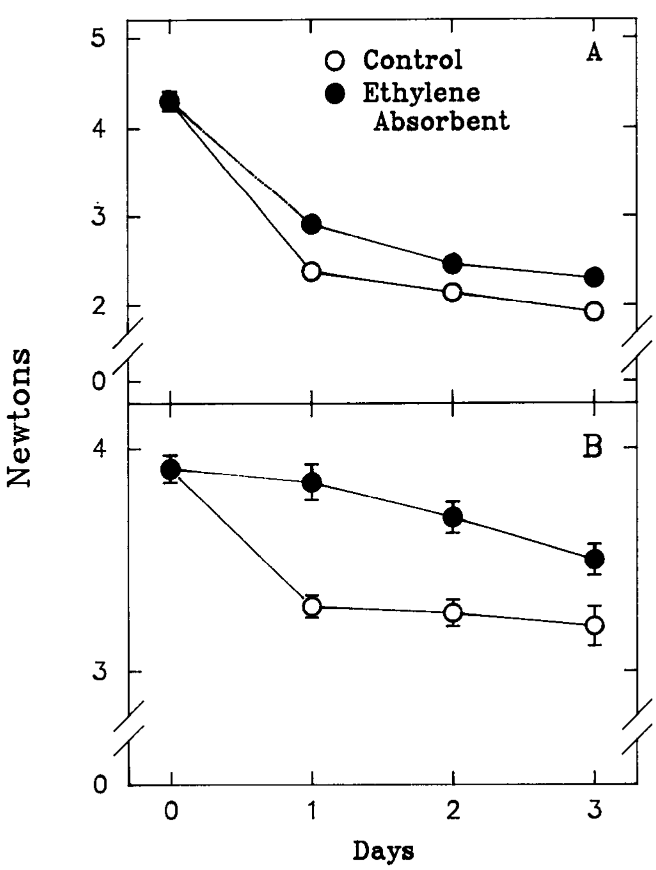

Fig. 3—Firmness of (A) pulp of kiwifruit slices and (B) banana sections stored with or without ethylene absorbent (Charcoal with palladium chloride) and held at 20°C.

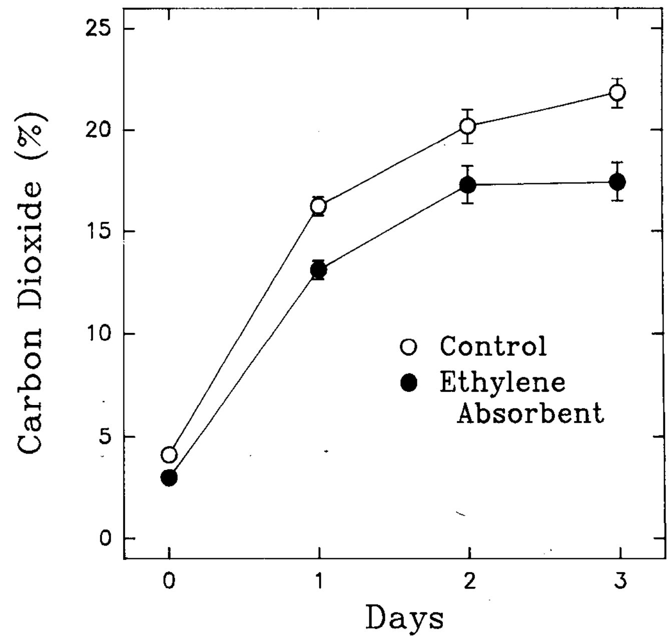

Fig. 4—Carbon dioxide concentration in kiwifruit slices and banana sections trays with and without ethylene absorbent. Trays held at 20°C.

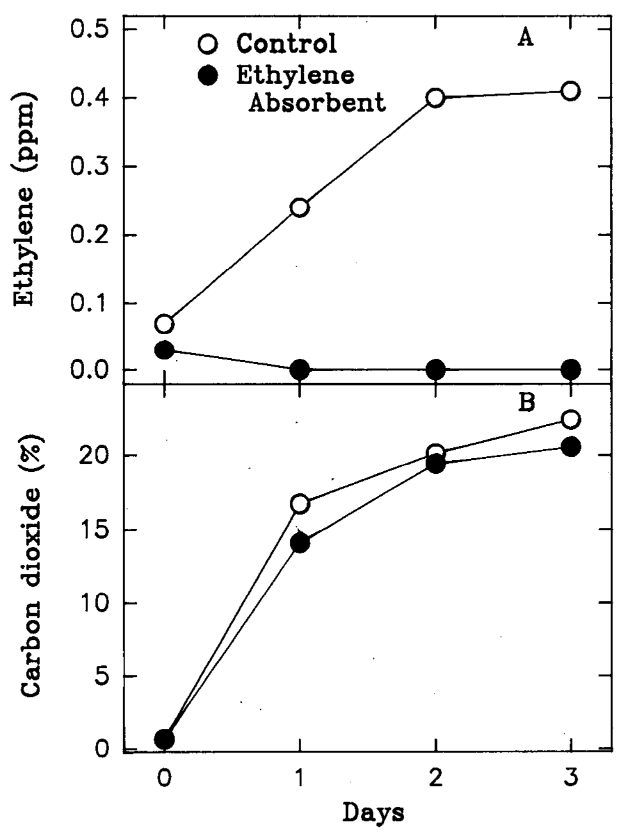

Fig. 5—(A) Ethylene and (B) carbon dioxide contents in broccoli and spinach trays with or without ethylene absorbent stored at 20°C.

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_2 and C_2H_4 contents were measured with TCD and FID gas chromatography, respectively.

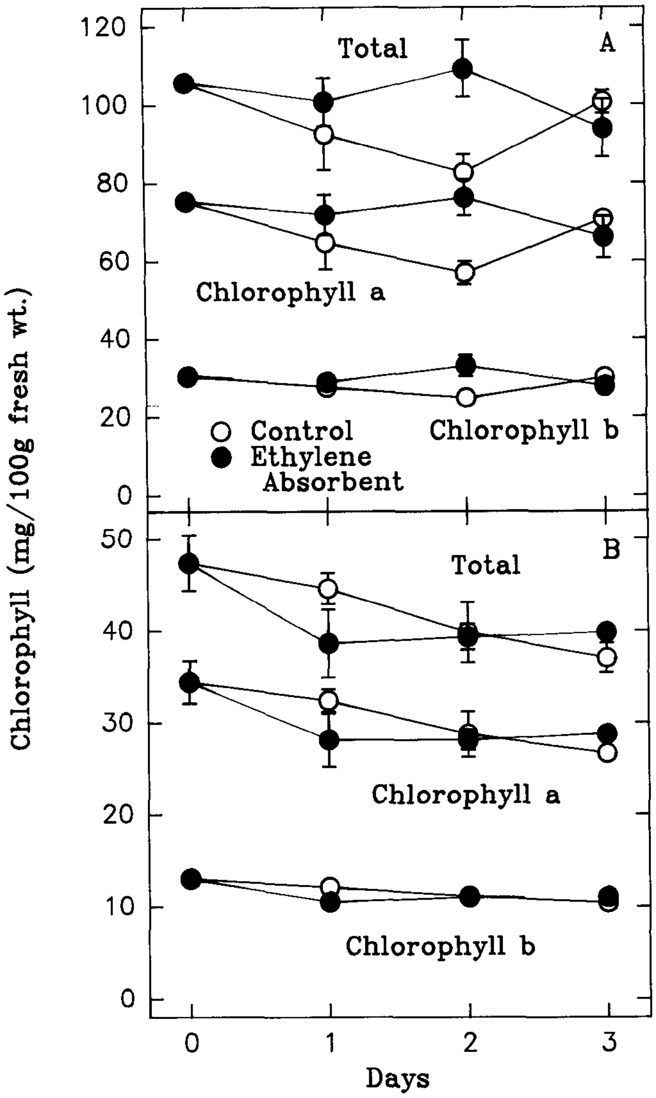

Fig. 6—Chlorophyll content of (A) spinach pieces or (B) broccoli pieces stored with or without ethylene absorbent and held at 20°C.

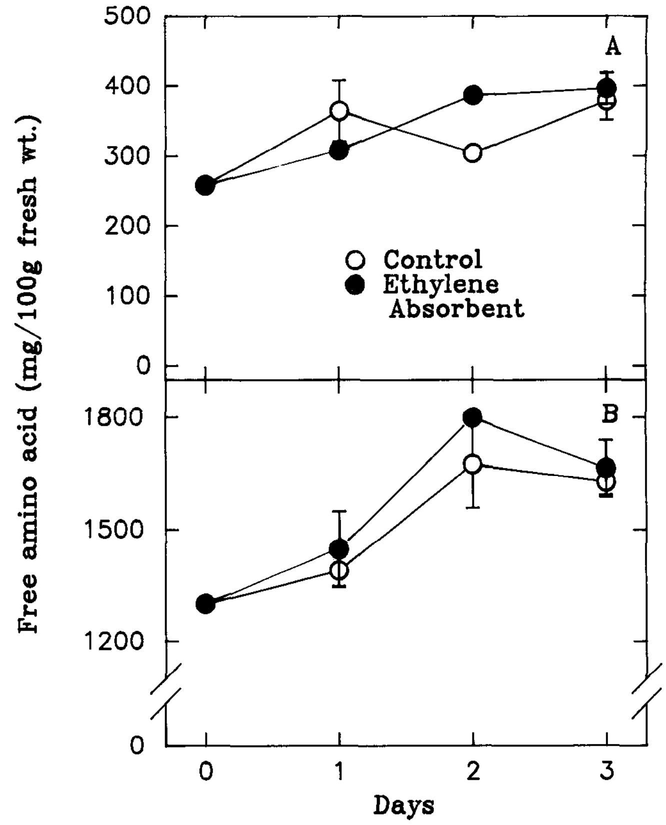

Fig. 7—Free amino acids content of (A) spinach pieces or (B) broccoli pieces stored with or without ethylene absorbent and held at 20°C.

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 without 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 broccoli 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_2H_4. The time period probably was not sufficient for metabolism to deteriorate with increased senescence.

CONCLUSIONS

C_2H_4 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_2H_4 with an absorbent, (charcoal with palladium chloride was very effective) is beneficial for maintaining the quality of lightly processed products.

REFERENCES

Arnon, D.I. 1949. Copper enzymes in chloroplasts. Polyphenol oxidase in *Beta vulgaris*. Plant Physiol. 24: 1.
Arpaia, M.L., Mitchell, F.G., Kader, A.A., and Mayer, G. 1985. Effects of 2% O_2 and varying concentrations of CO_2 with or without C_2H_4 on the storage performance of kiwifruit. J. Amer. Soc. Hort. Sci. 110: 200.
Bolin, H.R., Stafford, A.E., King, A.D., and Huxsoll, C.C. 1977. Factors affecting the storage stability of shredded lettuce. J. Food Sci. 42: 1319.
Friedman, B.A. 1951. Vacuum cooling of prepackaged spinach, cole slaw and mixed salad. Proc. Amer. Soc. Hort. Sci. 58: 279.
Hoffman, N.E. and Yang, S.F. 1982. Enhancement of wound-induced ethylene synthesis by ethylene in preclimacteric cantaloupe. Plant Physiol. 69: 317.
Kader, A.A. 1986. Biochemical and physiological basis for effects of controlled and modified atmospheres on fruits and vegetables. Food Technol. 40(5): 99.
Krahn, T.R. 1977. Improving the keeping quality of cut head lettuce. Acta Horticulturae 62: 79.
McGlasson, W.B. 1969. Ethylene production by slices of green banana fruit and potato tuber tissue during the development of induced respiration. Aust. J. Biol. Sci. 22: 489.
Moore, S. and Stein, W.H. 1948. Photometric ninhydrin method for use in the chromatography of amino acids. J. Biol. Chem. 176: 367.
Ohta, H. and Sugawara, W. 1987. Influence of processing and storage conditions on quality stability of shredded lettuce. J. Jpn. Soc. Food Sci. Technol. 34: 432.
Palmer, J.K. 1971. The banana. In *The Biochemistry of Fruits and their Products*, (Ed.) A.C. Hulme, Vol 2., p. 65. Academic Press, London and New York.
Priepke, P.E., Wei, L.S., and Nelson, A.I. 1976. Refrigerated storage of prepackaged salad vegetables. J. Food Sci. 41: 379.
Rosen, J.C. and Kader, A.A. 1989. Postharvest physiology and quality maintenance of sliced pear and strawberry fruits. J. Food Sci. 54: 656.
Sugawara, W., Kawano, S., Shiina, T., and Ohata, H. 1987. Quality control of shredded lettuce during preservation and distribution. J. Jpn. Soc. Cold Preservation Food. 13: 92.
Toivonen, P., Walsh, J., Lougheed, E.C., and Murr, D.P. 1982. Ethylene relationships in storage of some vegetables. In *Controlled Atmospheres for Storage and Transport of Perishable Agricultural Commodities*, (Ed.) D.G. Richardson and M. Meheriuk, p. 299. Timber Press, Beaverton, Oreg.
Watada, A.E. 1986. Effects of ethylene on the quality of fruits and vegetables. Food Technol. 40(5): 82.
Wolfe, S.K. and Robe, K. 1980. Modified atmosphere extends precut lettuce shelf life. Food Processing 41(9): 34.
Ms received 12/13/90; revised 6/9/91; accepted 7/13/91.

We acknowledge Dr. Judith A. Abbott of the Instrumentation and Sensing Laboratory and Mr. Willard Douglas for technical assistance.

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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.

REFERENCES

Boye, S.W. and Lanier, T.C. 1988. Effects of heat-stable alkaline protease activity of Atlantic menhaden (*Brevoortia tyrannus*) on surimi gels. J. Food Sci. 53: 1340.
Chang-Lee, M.V., Pacheco-Aguilar, R., Crawford, D.L., and Lampila, L.E. 1989. Proteolytic activity of surimi from Pacific whiting (*Merluccius productus*) and heat-set gel texture. J. Food Sci. 45: 1116.
Crisley, F.D., Peeler, J.T., Angelotti, R., and Hall, H.E. 1968. Thermal resistance of spores of five strains of *Clostridium botulinum* type E in ground whitefish chubs. J. Food Sci. 33: 411.
Cross, F.A. 1986. Menhaden. In *Southeast Fisheries Center 1986 Annual Report*, p. 16. U.S. Department of Commerce, National Oceanic & Atmospheric Administration, National Marine Fisheries Service, Washington, DC.
Douglas-Schwartz, M. and Lee, C.M. 1988. Comparison of the thermostability of red hake and Alaska pollock surimi during processing. J. Food Sci. 53: 1347.
Food and Drug Administration. 1984. *Bacteriological Analytical Manual*, 6th ed. Association of Official Analytical Chemists, Arlington, VA.
Johnson, J.M., Flick, G.J., Long, K.A., and Phillips, J.A. 1988. Menhaden (*Brevoortia tyrannus*): thermally processed for a potential food resource. J. Food Sci. 53: 323.
Lee, C.M. 1984. Surimi process technology. Food Technol. 38(11): 89.
Lynt, R.K., Solomon, H.M., Lilly, T. Jr., and Kautter, D.A. 1977. Thermal death time of *Clostridium botulinum* type E in meat of the blue crab. J. Food Sci. 42: 1022.
Lynt, R.K., Kautter, D.A., and Solomon, H.M. 1982. Differences and similarities among proteolytic and nonproteolytic strains of *Clostridium botulinum* types A, B, E and F: a review. J. Food Sci. 45: 466.
Lynt, R.K., Solomon, H.M., and Kautter, D.A. 1983. Effect of delayed germination by heat-damaged spores on estimates of heat resistance of *Clostridium botulinum* types E and F. J. Food Sci. 48: 226.
Ostle, B. and Mensing, R.W. 1975. *Statistics in Research*. Iowa State University Press, Ames, IA.
Pacheco-Aguilar, R., Crawford, D.L., and Lampila, L.E. 1989. Procedures for the efficient washing of minced whiting (*Merluccius productus*) flesh for surimi production. J. Food Sci. 54: 248.
Pflug, I.J. and Holcomb, R.G. 1983. Principles of thermal destruction of microorganisms. In *Disinfection, Sterilization, and Preservation,* 3rd ed. Block, S.S. (Ed.), p. 799. Lea and Febiger, Philadelphia, PA.
Smith, L.D.S. and Sugiyama, H. 1988. *Botulism. The Organism, Its Toxins, The Disease*, 2nd ed. Charles C Thomas, Springfield, IL.
Stumbo, C.B. 1965. *Thermobacteriology in Food Processing*. Academic Press, New York.
Yoon, I.H., Matches, J.R., and Rasco, B. 1988. Microbiological and chemical changes of surimi-based imitation crab during storage. J. Food Sci. 53: 1343.
Ms received 12/8/90; revised 3/7/91; accepted 6/6/91.

We thank Richard K. Lynt for valuable advice, assistance and suggestions regarding experimental protocol, and the Zapata Haynie Corp. for supplying menhaden surimi samples.