DIFFERENTIAL RESPONSE OF COLD STORED POTATO TUBERS TO ETHYLENE

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ABSTRACT

The chip color of two potato varieties (Monona and Kennebec) processed directly out of 40 F storage changed in different directions after short exposure to ethylene and continued cold storage. Monona tubers produced much darker chips after ethylene treatment whereas non-enzymatic browning of Kennebec chips was considerably less after gassing. The distribution of pigmentation in chips prepared from both tubers was more uniform after ethylene treatment.

The increasing rate of processed potato consumption since 1940 is indicated by the prediction that 75% of potato production for human consumption will be used for derived products by 1976 (Baxter, 3). An important aspect of the improvement and uniformity of processed product quality is the development of varieties, cultural and handling methods, and other *modus operandi* which yield cold-stored tubers with minimal tendency to darken via Maillard-type browning during processing. The eventuation of non-enzymatic browning in potato products, such as chips, is a manifestation of the chemical composition of the potato tuber; notably, the spectra of reducing sugars, organic acids, sucrose, amino acids, and perhaps other constituents whichh may directly or indirectly influence this reaction. The chemical constitution of tubers may be determined by variety (Akeley et al., 1), cultural practices (Hart and Smith, 6), environmental parameters (Yamaguchi et al., 15), physiological stage of development (Yamaguchi, 14), and postharvest storage conditions.

Much work has been devoted to studying the influence of storage temperatures below 55 F upon the accumulation of reducing sugars and other metabolic shifts which lead to extensive non-enzymatic browning during processing.

Ethylene gas, at ppm levels, is known to evoke physiological changes in plant tissue. The specific nature of metabolic response to ethylene varies with the nature of the tissue and other conditions. It is generally held that ethylene acts by altering the permeability of cellular membranes allowing the transport of otherwise compartmentalized metabolites, hormones or metabolic effectors. There is no indication in the literature of the processed quality of cold stored potato tubers after ethylene treatment, although recently, Reid and Pratt (12) demonstrated that White Rose tubers underwent a climacteric rise in respiration when treated with 10 ppm of ethylene for 24 hours.

The influence of ethylene treatment of cold stored Monona and Kennebec potato tubers on chipping quality is reported in this paper. These tubers have, respectively, a tendency to form light and dark products when processed directly out of cold storage (Deppen, 5).

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Materials and Methods

Wisconsin grown potatoes *S. tuberosum* (Monona and Kennebec) were stored at 40 F (90% relative humidity) for 3 months. The respiratory rate, as measured by titration of trapped CO_2 (Braverman, 4), and chip color (Potato Chip Institute International Color Reference Standard) were recorded at weekly intervals during the last month of storage prior to ethylene treatment. Tubers (3 Kg) were exposed to ethylene gas for 1 hour at 40 F, by adding 1 ml of 2-chloroethyl phosphonic acid (Amchem) to 250 ml of 0.2*N* NaOH in a closed chamber holding the samples. Chip color and respiration were measured at 4 days and at 1, 2, and 4 weeks after ethylene treatment. Tubers were not exposed to higher storage temperature ("conditioned") at any stage during these studies.

Chips were fried in corn oil, maintained at 375 F, until turbulent frothing ceased. In certain cases, raw potato slices were rinsed in distilled water for 5 minutes prior to chipping and in other cases the slices were processed directly.

Results and Discussion

Respiration:

The respiration rate of Monona and Kennebec tubers was steady during the third month of storage at 40 F (Table 1). The respiration of Monona tubers was considerably higher than that of Kennebec tubers during this period of cold storage. After exposure to ethylene and continued storage at 40 F, both groups of tubers showed an initially higher level of respiration followed by approximation of similar steady state levels of respiration. The magnitude of respiratory stimulation was similar in both groups of tubers. An earlier report by Heulin and Barker (7) showed similar response of cold stored tubers to ethylene exposure. The respiration rate may be important as it related to the steady state levels of reducing sugars in cold stored potatoes (Paez and Hultin, 8). The respiratory burst which accompanies removal of cold stored tubers to higher temperatures has been well studied. The lack of major respiration stimulation would suggest that ethylene treatment did not initiate metabolic changes directly analogous to conditioning at higher temperatures. The recent studies of Paez and Hultin (8) on potato mitochondria are also consistent with this observation.

Color of potato chips:

The color of potato chips prepared from Monona and Kennebec tubers was invariant for the 1 month storage prior to ethylene treatment (Table 2). The color scale (1-10) provided by the Potato Chip Institute International was used to judge overall non-enzymatic browning. A rating of 1 refers to an essentially white chip and a color index of 10 represents chips which are uniformly dark brown. The relatively light color of Monona chips prepared from tubers directly from cold storage and the darker color of chips prepared from Kennebec after same storage history is consistent with previous reports and related to accumulation of reducing sugars (Deppen, 5). In this regard, it is tempting to speculate on a possible relationship between the observed steady state respiration rates and reducing sugar levels during cold storage.

TABLE 1.—*Respiration (CO_2 Evolution) of Kennebec and Monona tubers at 40 F pre- and post-ethylene treatment.*

	mg CO_2/hr/kg tubers*	
Cold storage 40 F (weeks)	Monona	Kennebec
9	1.28	1.78
10	1.37	1.88
11	1.25	1.82
12	1.24	1.92
Ethylene treatment, 1 hour		
12½	2.48	3.40
13	1.80	2.70
14	1.35	2.10
16	1.25	1.87

*Data are average of four readings at indicated storage time and are representative of three such experiments.

TABLE 2.—*Index of potato chip color* from tubers directly out of cold storage.*

Cold storage 40 F (Weeks)	Monona	Kennebec
9	3	9
10	3	9
11	3	9
12	3	9
Ethylene treated, 1 hour		
12½	10+	4
13	10+	4
14	10+	4
16	10+	4

*Potato Chip Color Reference Standard, Potato Chip Institute International. Data are representative of three such experiments.

Tubers exposed to ethylene for 1 hour and subsequently stored at 40 F produced chips differing in two ways. In general, the distribution of pigmentation throughout the cross sectional slices was quite uniform when compared to that of chips from untreated tubers. In particular, the cortical area did not produce the characteristic lighter colored ring observed in control samples but was similar in color to the internal pulp. The known influence of ethylene on solute leakage in parenchymatic tissue (Sacher, 13) is consistent with the apparent uniformity in distribution of reducing sugars and amino acids after ethylene treatment.

The influence of ethylene treatment of tubers on chip color was different with the two varieties (Table 2). Monona tubers produced extremely dark chips directly out of cold storage after 4 days and throughout the 1 month test period. On the other hand, Kennebec tubers, which ordinarily yield dark chips out of cold storage, produced much lighter colored chips on cold storage after ethylene treatment.

Apparently, ethylene potentiated different rate limiting reactions in the two tuber systems. The possible role of invertase and invertase inhibitor in controlling the accumulation of reducing sugars in cold-stored potato (Pressey, 9, 10, 11) leads one to speculate that cellular decompartmentation resulting from ethylene treatment may influence some parameter of this control site such as availability of inhibitor, invertase or sugar compartments.

Literature Cited

1. Akeley, R. V., Audia, W. V. and Heinzy, P. H. 1965. Some newer potato varieties and their chipping qualities. Proc. Prod., and Tech. Div. Meetings. Potato Chip Inst. Intern., 9-10.
2. Anonymous. Potato Chip Color Reference Standard, Potato Chip Institute International, 940 Hanna Building, Cleveland, Ohio 44115.
3. Baxter, J. L. 1966. What does the future hold for processed potatoes? Sixteenth National Potato Utilization Conference Report, p. 9. Agricultural Research Service, USDA. ARS 74-40.
4. Braverman, J. B. 1963. Introduction to the Biochemistry of Foods, Elsevier, New York, pp. 336.
5. Deppen, J. 1968. The effect of Potato Varieties and storage temperatures upon the rates of accumulation of monosaccharides, disaccharides, organic acids, and amino acids. Ph.D. Thesis Order 69-4869.
6. Hart, T. G. and Smith, O. 1966. Potato Quality XXVII. The role of phosphorus in potato chip browning. Amer. Potato J. 43: 158.
7. Heulin, F. E. and J. Barker. 1939. The effect of ethylene on the respiration and carbohydrate metabolism of potatoes. New Phytol. 38: 85-104.
8. Paez, L. and Hultin, H. O. 1970. Respiration of potato mitochondria and whole tubers and relation to sugar accumulation. J. Ed. Sci. 35: 46.
9. Pressey, R. 1966. Separation and properties of potato invertase and invertase inhibitor. Arch. Biochem. Biophys. 113: 6671.
10. Pressey, R. 1967. Invertase inhibitor from potatoes: purification, characterization, and reactivity with plant invertases. Plant Phys. 42: 1780.
11. Pressey, R. 1969. Role of invertase in the accumulation of sugars in cold-stored potatoes. Amer. Potato J. 46: 291.
12. Reid, M. S. and H. K. Pratt. 1970. Ethylene and the respiration climacteric. Nature 226: 976.
13. Sacher, J. A. 1962. Relations between changes in membrane permeability and the climacteric in banana and avocado. Nature 195: 577.
14. Yamaguchi, M., H. Timm, H. D. Clegg and F. D. Howard. 1966. Effect of maturity of postharvest conditions on sugar conversion and chip quality of potato tubers. Proc. Amer. Soc. Hort. Sci. 89: 456.
15. Yamaguchi, M., H. Timm and A. R. Spurr. 1964. Effects of soil temperature on growth and nutrition of potato plants, and tuberization, composition, and periderm structure of tubers. Proc. Amer. Soc., Hort. Sci. 84: 412.