The Effect of Composition of the Atmosphere and Duration of Exposure on Brown Stain of Lettuce\textsuperscript{1, 2}

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Abstract. The severity of brown stain on crisphead lettuce \textit{(Lactuca sativa L., cvs. Calmar and Great Lakes 118)} held at 0\textdegree{} or 2.5\textdegree{}C for 10 days increased with increasing CO\textsubscript{2} (1 to 5\%) and decreasing O\textsubscript{2} (21 to 1\%) levels. Very slight or no brown stain developed on lettuce subjected to 0, 1, or 2\% CO\textsubscript{2} in combination with 10 or 21\% O\textsubscript{2} for 10 days or on that held in 2.5 or 5\% CO\textsubscript{2} + 2\% O\textsubscript{2} for 4 days at 2.5\textdegree{}C. In 2.5 or 5\% CO\textsubscript{2} + 2\% O\textsubscript{2}, brown stain intensified with duration of exposure (2 to 30 days) at 0\textdegree{} or 2.5\textdegree{}C.

The effects of modified atmospheres on the market quality and physiological disorders of crisphead lettuce have been reported (3, 4, 6, 7, 8, 13). Brown stain is a physiological disorder of head lettuce that can be induced by increased CO\textsubscript{2} in the atmosphere (8). The severity of brown stain is influenced by the concn of CO\textsubscript{2} and O\textsubscript{2} in the atmosphere (11), by temp during and after exposure to CO\textsubscript{2} (1), and by cultivar and area of production (2, 10). It is enhanced by added CO (12). This report shows the effect on brown stain induction of exposure to 4 levels of CO\textsubscript{2} combined with 5 levels of O\textsubscript{2} under conditions of time and temp conducive to the disorder. Another factor not previously examined is the effect of durations of exposure to brown stain-inducing conditions on which we now also report.

Materials and Methods

During the seasons of 1970-1972, 16 tests were conducted with ‘Calmar’ and ‘Great Lakes 118’ lettuce grown in the Salinas Valley to determine the effects of various combinations of CO\textsubscript{2} and O\textsubscript{2}. Since the results were similar for both cultivars, we report here the results of 7 tests with ‘Calmar’ conducted during the period of August to October, 1972. The treatments included 1, 2, 5, 10, or 21\% O\textsubscript{2} in combination with 0, 1, 2, or 5\% CO\textsubscript{2} at 2.5\textdegree{}C for 10 days. Not all of the 20 controlled atmosphere (CA) treatments were included in each of the 7 tests; however, each treatment was included in at least 2 tests.

To evaluate duration of exposure, ‘Great Lakes 118’ lettuce harvested in July 1971 was subjected to various brown stain inducing treatments for 2 to 30 days at 2.5\textdegree{}C. In addition, ‘Calmar’ lettuce harvested in July 1972 was held under 2\% O\textsubscript{2} + 5\% CO\textsubscript{2} at 0\textdegree{}C for periods of 2 to 14 days.

In all tests the lettuce was vacuum cooled to about 2\textdegree{} to 4\textdegree{}C in the Salinas area before transportation to Davis under conditions protecting it from temp increases of more than 2\textdegree{} to 5\textdegree{}C. The samples (8 or 10 heads per treatment) were prepared and placed under differential treatments on the day of harvest, as previously described (1, 2). Following the desired holding period at 0\textdegree{} or 2.5\textdegree{}C under CA treatment, the lettuce was held for 4 days in air at 10\textdegree{}C to simulate marketing conditions and permit development of symptoms (1, 11). The heads were then evaluated externally and internally for brown stain and the results were expressed as an average index that includes the estimated size, number and degree of discoloration of lesions (2). In these tests, symptoms observed closely resembled those described by Lipton et al. (5).

Results

Effects of CO\textsubscript{2} and O\textsubscript{2} concentration. With ‘Calmar’, the severity of brown stain following holding for 10 days at 2.5\textdegree{}C depended upon both the CO\textsubscript{2} and O\textsubscript{2} levels during the exposure, Fig. 1. For each level of O\textsubscript{2}, the brown stain index
levels of 0, 1, 2, and 5%, respectively.

In 'Great Lakes 118' held for various durations at 2.5°C and 2% O₂, the brown stain increased with increases in CO₂ level and the difference between 5% and 2.5% CO₂ treatments was especially marked for exposures of 6 days or longer (Fig. 2). For example, lettuce stored for 10 days at 2.5°C in 5% CO₂ exhibited approximately 5 times as much brown stain (as indicated by the degree of discoloration, size and number of lesions) as lettuce held in 2.5% CO₂ under the same conditions. Effect of duration of exposure. The effect of duration of CA treatment was dependent on storage temp and on levels of CO₂ and O₂. In 'Great Lakes 118' lettuce held at 2.5°C, brown stain increased with time of exposure to 2.5 or 5% CO₂ (Fig. 2). Very slight or no brown stain was noticed on lettuce subjected to 0 or 1% CO₂ for up to 30 days at 2.5°C. This was also true for the 2.5 and 5% CO₂ levels for the first 4 days in storage. While the severity of brown stain increased, on lettuce held in 2.5% CO₂, with time over the entire 30-day period at 2.5°C; it reached near maximum after 10 days on lettuce subjected to 5% CO₂ (Fig. 2). In contrast, 'Calmar' held at 0°C under the same CA treatment exhibited increased amounts of brown stain over all increased with elevated levels of CO₂ (0, 1, 2, or 5%) except 1% vs. 0% in the presence of air where no brown stain occurred in either treatment. Many of the differences were not statistically significant as measured by analysis of variance but the trend is definite within each O₂ level and the response appears to be exponential. The correlation coefficients for brown stain index vs. CO₂ concen were 0.98, 0.98, 0.95, 0.96, and 0.94 at O₂ levels of 1, 2, 5, 10, and 21%, respectively.

For each CO₂ level, brown stain increased as the O₂ level was decreased (21, 10, 5, 2, or 1%) except for 10% vs. 21% with no added CO₂ and 2% vs. 5% at 5% CO₂ (Fig. 1). Again, the differences between 2 levels of O₂ were not significant in many comparisons but the trend was definite at each level of CO₂. The effect of O₂ level became more important at levels of 5% and below. The correlation coefficients for brown stain index vs. O₂ concen were -0.86, -0.88, -0.89, and -0.92 at CO₂

Fig. 1. Effect of O₂ and CO₂ concen on brown stain severity in 'Calmar' lettuce held at 2.5°C for 10 days, followed by 4 days at 10°C in air. The brown stain index is based on the degree of discoloration, and size and number of lesions. Values shown represent the mean index of 16-30 heads from 7 tests. LSD (0.05) = 11.

Fig. 2. Brown stain severity in 'Great Lakes 118' lettuce as affected by duration of exposure to 0, 1, 2.5, and 5% CO₂ in combination with 2% O₂ at 2.5°C, followed by 4 days at 10°C in air. Values shown represent the mean indices of 8-head samples. LSD (0.05) = 13.

Fig. 3. Brown stain severity in 'Calmar' lettuce as affected by duration of exposure to 2% O₂ + 5% CO₂ at 0°C, followed by 4 days at 10°C in air. Values shown represent the mean indices of 8-head samples. LSD (0.05) = 14.

durations up to 14 days (Fig. 3). This difference in the effect of duration of CA exposure on brown stain development for these 2 cultivars is attributed to temp as well as to differences in response of cultivars to CO2 injury.

Discussion

CO2 and O2 levels vary greatly in lettuce containers under actual transit conditions (9). To date, only a few levels of O2 (2-3% and 21%) in combination with increased CO2 have been studied in detail (1, 2, 11). These workers have shown that 2 to 3% O2 in combination with increased CO2 increases brown stain. Our results are similar and show that levels of O2 of 1, 2, or 5% in combination with increased CO2 noticeably increased brown stain relative to 10 and 21% O2. In contrast, it has been reported (13) that the harmful effects of increased CO2 (1, 2.5, 5, and 20%) on lettuce stored at 5°C (a temp not indicative to brown stain incidence) did not seem to be changed by reduction of O2 levels (1, 2.5, 5, and 20%). According to these same workers, a reduction of O2 content down to 2% had little or no value in maintaining visual quality during short storage periods (10 days or less). Our data generally agree with these findings, except that lettuce predisposed to pink rib or russet spotting maintains visual quality better in low O2 atmospheres by reducing the incidence of these disorders. Interestingly, brown stain occurred in treatments without added CO2 only when O2 levels were below 5%. As previously pointed out (1), brown stain in these 0% CO2 treatments may be due to accumulation of respiratory CO2, which ranged between 0.2 and 0.5%. The observation that low O2 enhances the development of brown stain raises the question as to whether low O2 can induce symptoms indistinguishable from brown stain because of an effect comparable to that of increased CO2 or whether it simply enhances CO2 injury. Perhaps either lowered O2 and increased CO2 at temp below 5°C could favor the accumulation of harmful metabolites that, in turn, elicit brown stain symptoms.

Our data show that if the O2 level is 5% or above, CO2 levels up to and including 2% can be tolerated during transit or storage of head lettuce at 2.5°C. Even CO2 levels of 2.5 or 5% + 2% O2 can be tolerated for a short duration (up to 4 days) at 2.5°C.

The effect of modification of the atmosphere as a supplementary treatment to temp control during transit or storage of crisphead lettuce seems to be dependent on temp, conc of O2, CO2, and CO and duration of the exposure (1, 2, 11, 12). It should be kept in mind that there is a definite interaction between composition of the atmosphere and temp (1). These factors as well as variation in cultivar susceptibility to various physiological disorders may explain the conflicting results in the literature. Thus it is essential to take into consideration cultivar, preharvest conditions, temp, and duration of exposure when evaluating the effects of gaseous combinations on lettuce.

Literature Cited


