Prevention of Tipburn in Iceberg Lettuce During Postharvest Storage

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ABSTRACT

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Tipburn, an abiotic necrotic breakdown of marginal leaf tissue of iceberg lettuce (*Lactuca sativa* var. *capitata*), was consistently induced in field-grown, detached iceberg lettuce heads by high storage temperature, e.g., 25 C for 7 days or 28 C for 4 days. However, tipburn was prevented if most stem tissues were removed before the temperature treatment. By contrast, removal of between 14 and 40% of the stem tissue (by weight) did not result in significant ($P = 0.05$) changes in the incidence and severity of tipburn.

Tipburn is the most important abiotic disorder of head lettuce, *Lactuca sativa* var. *capitata* L. (1,4,8,9,15,18). It occurs sporadically but usually is more prevalent in crops that mature during periods of relatively high temperature (above 25 C) in both fall and spring plantings. The disease is characterized by a necrotic breakdown of the marginal leaf tissue within the heads and a darkening of veins in affected areas. Most plantings are not affected severely, because the place and time of commercial planting usually are chosen to avoid hot weather around harvest time. Symptoms generally are restricted to leaves inside the heads and thus are evident only after removal of several outer leaves. This hidden symptomology prevents selective harvest of uninfected heads; consequently, fields with even a small percentage of diseased plants often are abandoned. Temperature, rapid growth, and calcium nutrition seem to play a major role in the development of the disease (1-3,7-10,12,13, 15-17). Except for the use of tolerant cultivars, no satisfactory method for tipburn control has been developed (11).

We have previously shown that tipburn can be induced in harvested lettuce within 4 to 7 days of storage at 24-33 C. Tipburn severity was also enhanced by enclosing mature intact lettuce in the field for 6 days with polyethylene-covered frames that raised head temperatures about 6.6 C above the ambient temperature outside the enclosure (13-26.6 C) (8). Moreover, the incidence and severity of the disease increased directly with time of exposure to tipburn-inducing temperatures (8). The effect of temperature on tipburn development was cumulative. Under laboratory conditions, tipburn developed about twice as fast when heads were kept continuously at 24-35 C compared with 12 hr in light at 24-35 C followed by 12 hr in the dark at 21 C. Moreover, the sums of hourly temperatures above 24 C required for tipburn induction in 50% of the heads were fairly close in constant or alternating temperature treatments (8). So tipburn, which is generally considered a preharvest problem, can be induced and developed after harvest when the storage temperature is kept above 24 C, the minimum temperature for tipburn induction under laboratory conditions (8).

Normally, lettuce is promptly cooled to 10-15 C after harvest and then stored at 10-15 C to extend its shelf life. This temperature range is low enough to prevent tipburn development. In our laboratory studies, no tipburn developed in heads kept below 24 C, even after 10 days' exposure (8). However, harvested lettuce is subjected, often inadvertently, to temperatures much above the ideal for different times in storage and/or transit because of inadequate precooling (vacuum cooling), restricted circulation of cool air due to tight load configuration, insufficient or malfunctioning refrigeration systems, and inadequately equipped carriers (4). Moreover, lettuce heads may remain for different lengths of time on nonrefrigerated grocery shelves. The exposure of lettuce to elevated temperatures, even for a short period, may result in tipburn initiation and/or development (8). For example, from 1972 to 1984, 54% of 3,923 shipments of naked (unwrapped) iceberg lettuce from Arizona and 42% of 16,559 shipments from California inspected at New York market had tipburn (4). Requests for inspections were principally made by receivers and in many cases involved shipments with questionable acceptance quality. Nevertheless, the high incidence of tipburn found was undoubtedly due to initiation and/or development of tipburn in transit, because lettuce is inspected in the field before harvest, and fields with more than 3% tipburn are rejected.

Other than maintaining low temperature in storage and transit, no other procedure is known for postharvest management of tipburn. We reported earlier the results of our cursory observation that the removal of stem tissue of detached, mature iceberg lettuce before exposure to tipburn-inducing temperatures prevented tipburn development in storage (9). We present here the results of our repeated quantitative field studies, which showed that the removal of the entire stem tissue was highly effective for controlling tipburn development in storage.

MATERIALS AND METHODS

Heads of mature iceberg lettuce cvs. Calmar, Empire, Salinas, and Calicel were collected randomly from commercial fields throughout Arizona. Within 8-20 hr after harvest, heads were randomly separated into three groups. One group was rated for the incidence and severity of tipburn. The entire stem tissue was removed from each head in the second group, and the stems in the third group were left intact. Heads in the second and the third groups were randomly placed, stem-end down, inside incubators at 25 ± 2 C for 7 days or at 28 ± 2 C for 4 days in the dark. The relative humidity was not controlled, and levels measured were between 34 and 47%. The heads were rated for tipburn severity at the end of the experiment by cutting them open and examining each leaf for the presence of characteristic symptoms of the disease. There were between 12 and 20 heads in each treatment in each of the six experiments. Each head served as one replicate.

Tipburn severity was rated on a scale from 0, no symptoms, to 3, severe symptoms. The experiment was repeated six times in fields in Marana (altitude 680 m), Aguila (720 m), and Yuma (40 m), Arizona, in April 1985, May 1985, April 1986, and April 1990. These areas are located at about 34 degrees north latitude. Differences between treatments in each experiment were statistically analyzed using the Mann-Whitney test in SPSS/PC (SPSS Inc., Chicago, Illinois). Nonparametric tests were used for all statistical analyses because the data were not normally distributed.

In two additional experiments, the stem tissue of lettuce cv. Salinas, from fields in Yuma in February and March 1992, was only partially removed. This was done by removing 12-, 16-, and 20-mm-diameter cores from the center of stems all the way to the growing points

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with cork borers nos. 6, 8, and 12. The average amounts of stem tissue removed were 14, 26, and 40% (by weight), respectively. Heads with excised, partially excised, and intact stem tissues were randomly placed, stem-end down, inside incubators at 28 ± 2 C for 4 days in the dark and rated for tipburn as described above. There were between 14 and 16 heads in each treatment of experiment 1 and 14 heads in each treatment of experiment 2. Each head served as one replicate. Differences between treatments in each experiment were statistically analyzed as described earlier.

RESULTS AND DISCUSSION

The incidence of tipburn in heads before the high-temperature treatment ranged from 0 to 12.5%, and the severity of tipburn was near 0 in all experiments (Table 1). Tipburn symptoms (necrotic breakdown of marginal leaf tissue and darkening of veins in the affected area), identical to those occurring in the field, developed in heads with intact stem tissue following exposure to 25 ± 2 C for 7 days or to 28 ± 2 C for 4 days (Table 1). Tipburn incidence in this group ranged from 80 to 100%, and average tipburn severity ranged from 0.5 to 1.75 on a scale of 0 to 3 (Table 1). In contrast, after temperature treatment tipburn incidence in heads with excised stem tissue was low, ranging from zero to 14%, and severity was rated near zero in all experiments (Table 1). Tipburn severity ratings in controls (heads with intact stem tissue after temperature treatment) varied among experiments (Table 1). The differences in ratings were most likely due to environmental and soil factors before harvest and to differential tolerances of lettuce cultivars in different experiments.

Removal of 14, 26, and 40% of stem tissue (by weight) before temperature treatment resulted in a 6% decrease, no change, and a 12% decrease, respectively, in tipburn incidence relative to controls after temperature treatment and in decreases of 13%, 13%, and no change in tipburn severity. However, tipburn incidence and severity ratings in heads with partially detached stems did not differ significantly ($P = 0.05$) from those with intact stems. In contrast, removal of the entire stem did prevent disease. Therefore, tipburn initiation and/or development in harvested iceberg lettuce can be prevented in nonrefrigerated storage by removing the entire stem tissues within 8–20 hr after harvest.

Removal of the entire stem tissue resulted in a slight darkening of the cut tissue. However, the darkening was very superficial (2–3 mm deep) and was reduced appreciably by wrapping lettuce heads in plastic sheets after removal of the stems. Some growers wrap lettuce in plastic to extend shelf life. The cut resulting from removal of the stem tissue did not become infected during the storage treatment of either wrapped or unwrapped lettuce.

The average weight loss of lettuce after 4 days of storage at 28 ± 2 C in commercial lettuce boxes was 4.8% in heads with intact stem tissue and 4.9% in heads with excised stem tissue. The respective average percent moisture loss under the above conditions was 3.3 and 3.7%. Thus, the removal of the stem tissue may not affect lettuce shelf life.

A simple device resembling a cork borer (35-mm diameter) is being used in a vegetable processing plant in Yuma, Arizona, for removal of stem tissue before shredding of head lettuce. The device is mounted horizontally on a platform with its cutting edge facing a worker. Stems are removed manually by pressing the stem-end of the lettuce heads against the cutting edge of the device. Similar devices may be used commercially for the removal of stem tissue in cases where the lettuce cultivar is known to be highly susceptible to tipburn, the disease is present at harvest, or when the harvested crop is likely to remain at temperatures above 24 C for more than a few hours.

The relative humidity in the growth chambers was not controlled during the exposure of lettuce heads to tipburn-inducing temperatures, because relative humidity was previously found not to influence tipburn development in mature detached heads under the conditions used in the study (8). The tests also were conducted in the dark, because light does not significantly influence tipburn development in storage (8).

Results of the study provide additional support for the view that tipburn development is directly correlated with growth (5,6,14–16). The suppression of tipburn in heads with excised stem tissue apparently is due to reduction of growth, because removal of stem tissue of half sections of heads resulted in substantial decreases in the growth of inner leaves during temperature treatment (9). In mature detached heads subjected to tipburn-inducing temperatures, symptoms occurred on central leaves, which exhibited appreciable growth during the temperature treatment, whereas middle and outer leaves, which grew only slightly, were usually symptomless. Moreover, no tipburn developed on detached young or old leaves kept under different temperatures and relative humidity regimes (8). The suppression of growth in heads with excised stem tissue could be due to the elimination or reduction of the supply of hormones and nutrients that may be stored in the stem tissue.

The finding that tipburn development can be suppressed by removal of stem tissue may be useful in future studies designed to elucidate the physiological basis of tipburn development.

Table 1. Tipburn incidence and severity ratings of detached iceberg lettuce heads with intact and excised stem tissues before and after exposure to tipburn-inducing temperature[x]

	Tipburn incidence[y]			Tipburn severity[z]		
Experiment	Before exposure	After exposure (intact stem)	After exposure (excised stem)	Before exposure	After exposure (intact stem)	After exposure (excised stem)
1	2/16	16/18	2/14	0 d (0–0.5)	0.5 d (0–2.0)	0 e (0–1.0)
2	0/17	12/14	0/15	0 d (0)	0.5 d (0–1.5)	0 e (0)
3	0/14	12/15	0/14	0 d (0)	0.5 d (0–1.5)	0 e (0)
4	1/20	16/19	0/18	0 d (0–0.5)	1.0 d (0–2.0)	0 e (0)
5	0/12	17/19	0/14	0 d (0)	1.0 d (0–2.5)	0 e (0)
6	1/14	16/16	1/16	0 d (0)	1.75 f (1.0–2.0)	0 e (0–0.5)

[x] Cultivars Calmar, Empire, and Calicel were used for experiments 1 and 4, 2 and 3, and 5 and 6, respectively. Within 8 to 20 hr after harvest, heads were randomly separated into three groups. One group was rated for the incidence and severity of tipburn. The entire stem tissue was removed from each head in the second group, and the stems in the third group were left intact. Heads in the second and the third groups were randomly placed, stem-end down, inside incubators at 25 ± 2 C for 7 days or at 28 ± 2 C for 4 days in the dark and then rated for tipburn incidence and severity. There were between 12 and 20 single-head replicates in each treatment for each experiment.

[y] Number of tipburned plants/number of plants tested.

[z] Average tipburn severity, as rated on a scale from 0 (no symptoms) to 3 (severe symptoms). Figures in parentheses represent ranges. Values not followed by the same letter were different at $P = 0.05$ in Duncan's multiple range test.

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