
**Deterioration and CO₂ and Ethylene Production of Stored Mung Bean Sprouts**

**Werner J. Lipton, Wesley K. Asai**, and **David C. Fouse**

*Market Quality and Transposition Research Laboratory, Science and Education Administration, U.S. Department of Agriculture, P.O. Box 8143, Fresno, CA 93747*

Additional index words. chilling injury, Phaseolus aureus, temperature quotient, Vigna radiata

**Abstract.** The mean rate of deterioration of green gram mung bean (Vigna radiata [L.] R. Wilcz.) sprouts stored at 0, 2.5, 5 or 10°C increased linearly with temperature. The sprouts reached the lower limit of salability in about 8.5, 5.5, 4.5 and 2.5 days at the respective temperatures. There was no symptom of chilling injury. The rates of CO₂ production were 23, 29, 42 and 96 mg/kg—hr, at 0, 2.5, 5 and 10°C, respectively, when measured 1 day after the sprouts were harvested. The corresponding rates of ethylene production were 0.15, 0.05, 0.24 and 0.90 μl/kg-hr.

Mung bean sprouts are a dietary staple in the Far East and are available in most supermarkets and in many restaurants throughout the United States. Although no official statistics on bean sprout production are collected in this country, United States annual production of mung bean seeds for sprout production is estimated to be about 8.3 million kg (W. R. Ottmanns, Palecek Mills, Inc., Enid, Oklahoma, personal communication). Since each kg of seed produces between 6 and 7 kg of sprouts, total production of bean sprouts in the United States probably amounts to at least 50 million kg annually. In spite of their importance as a fresh or cooked vegetable, and as a good source of vitamins, especially of ascorbic acid (2), information on the postharvest behavior of mung bean sprouts is scant (7). We, therefore, determined the mode and rate of deterioration and the rates of CO₂ and of ethylene production of sprouts held at various constant temperatures. Such information is of intrinsic interest and may aid in quality maintenance of bean sprouts during marketing. Currently, the sprouts displayed in many markets have brown-speckled cotyledons and leaflets instead of light yellow ones and undesirably dark hypocotyls and radicles.

**Materials and Methods**

We used sprouts of the green gram mung bean (Vigna radiata, cultivar unknown; formerly Phaseolus aureus Roxb.) (1), from a commercial grower who had sprouted them for 6 days at about 21°C. After harvest, the sprouts were washed with fresh tap water and the excess moisture was removed from them in a slowly revolving centrifuge. About 4.5 kg of the sprouts were placed in plastic bags and transported to the laboratory. For all tests, we placed 500 g (± 1 g) of sprouts loosely into glass respiration jars
(ca 10 liter capacity) in which they were supported by a stainless steel screen. Water (100 ml) and paper towels were put in the bottom of the jars to maintain a high relative humidity. All experiments began within 3 hr of harvest.

The holding period was varied with the temperature and ranged from a maximum of 4 days at 10°C to 7 days at 0, 2.5, and 5°C, all ± 0.5°. Storage at the 3 lower temperatures was followed by 1 day at 10° to simulate conditions of retail display. Each test at 0, 2.5, and 5° consisted of 12 samples, with 2 samples being evaluated at each of the examinations. At 10° only 6 samples were needed because there was no additional holding period at a higher temperature. We conducted 3 tests at each temperature; thus, the means are based on 6 samples.

Air flow through the jars was adjusted to maintain the CO₂ level in the effluent below 0.5%; the flow was 80 ml/min (± 2 ml) at 0, 2.5, and 5°C and 200 ml/min (± 5 ml) at 10°; thus 1 air change occurred during each 2 hr and 0.8 hr, respectively. CO₂ content of the effluent air stream was measured with a Fisher Gas Partitioner (Model 1200; thermal conductivity detector) equipped with a 198 x 0.32 cm, 80/100 mesh Columpak PQ column and a 335 x 0.48 cm column packed with 60/80 mesh molecular sieve 13 x. Ethylene concentration was determined with a Carle (Model 211) gas chromatograph equipped with a flame-ionization detector and a 120 x 0.48 cm column packed with 80/100 mesh alumina. Sample sizes were 0.5 ml for CO₂ and 2.0 ml for ethylene determinations and the samples were collected with a hypodermic syringe via a T in the effluent line. The measurements generally were made once or twice a day.

We subjectively evaluated color of the cotyledons, first true leaves, hypocotyls and radicles; odor of the mass of sprouts; and the general size of the first true leaves. We rated degree of sliminess not visibly associated with decay, and severity of decay on a scale of 1 = none to 9 = extreme and general appearance on a scale of 9 = excellent to 1 = extremely poor (3). In each of the 3 tests conducted at 10°C, we also measured the initial and final length (± 1 mm) of 10 hypocotyls. The relationship between rate of deterioration and storage temperature was tested by regression analysis. The rate of deterioration is expressed in rating units/day, where, for example, a change from a rating of 9 to 7 is equivalent to 2 rating units.

**Results and Discussion**

Major symptoms of deterioration were (a) darkening of the sprouts, (b) development of sliminess, decay, and musty odors, and (c) increased streaking of hypocotyls.

*Changes in color.* In fresh sprouts the hypocotyls were white. Upon aging, they darkened to a light buff and eventually to beige and light tan. This darkening became perceptible when sprouts were held 6 to 7 days at 0°C, but much sooner in those held at higher temperatures (Table 1). Upon transfer of the sprouts to 10°C, the hypocotyls remained white for 2 or 3 days when they were previously stored at 0° and for 2 days if they had been stored at 2.5° or 5°.

Some hypocotyls developed 1, or usually 2, light tan to rusty brown streaks, mainly along the lower portion of the axis (Fig. 1). However, in 3 tests the streaks were already evident in 5 to 10% of

---

**Table 1.** Intervals between harvest and appearance of discolorations, sliminess and decay in mung bean sprouts and their deterioration to the lower limit of salability at various temperatures.

<table>
<thead>
<tr>
<th>Storage temp (°C)</th>
<th>Structures discolored</th>
<th>Lower limit of salability</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hypocotyls² Radicles³ Cotyledons⁴ Leaves⁵ Sliminess⁶ Decay⁷</td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>6 to 7</td>
<td>5</td>
</tr>
<tr>
<td>2.5</td>
<td>5 to 7</td>
<td>3 to 5</td>
</tr>
<tr>
<td>5</td>
<td>4 to 6</td>
<td>3 to 5</td>
</tr>
<tr>
<td>10</td>
<td>2</td>
<td>1 to 2</td>
</tr>
</tbody>
</table>

*²Days required for hypocotyls to perceptibly darken.
³Days required for radicle to become light tan.
⁴Days required for cotyledons to become brown; usually 10% of sprouts affected.
⁵Days required for about 10% of first true leaves to show necrotic spots or areas.
⁶Days required to reach rating of 3 (slight).
⁷Days required to change from rating of 9(excellent) to 5 (lower limit of salability).
the hypocotyls at time of harvest and their incidence varied among batches of sprouts. After 1 week at 0°C or 2.5°C or after 2 or 3 days at 5°C, the incidence ranged from less than 1% to about 20%, but about doubled during the subsequent day at 10°C. For sprouts continually stored at 10°C, the incidence also ranged widely, from about 1% to 70%, even after only 2 days. The location of the streaks was not related to any macroscopically or microscopically visible structural feature of the hypocotyl. There also was no evidence of fungal or bacterial infection. Possibly, a group of cells was injured before or during germination, and, as these or adjacent cells expanded, the injured area became elongated (D. J. Phillips, personal communication).

Darkening of the radicle is another color change associated with deterioration of mung bean sprouts. The change from light beige to light tan was most rapid at 10°C, slightly slower at 2.5° and 5° and slowest at 0° (Table 1). The additional day at 10°C had little effect on radicle color for sprouts stored at 0°C, but caused the color to become tan to brown in those that had been stored at 2.5° or 5°.

The cotyledons of fresh sprouts were yellow, occasionally with purple spots, and they always were shrivelled. Browning, the chief symptom of deterioration in cotyledons, developed much more slowly at 0°C than at the higher temperatures (Table 1). Usually, fewer than 10% of cotyledon pairs were discolored, even after the additional day at 10°C. In 1 test at 2.5°C, however, the incidence had reached 10% after 1 day, 20% after 6 days, and doubled during the additional day at 10°C.

The first true leaves generally remained a desirable yellow throughout 7 days of storage at 0°C or 2.5°C. However, about 10% developed necrotic spots or they turned uniformly brown within 2 days at 5°C or 10°C (Table 1). Transfer from the lower temperatures to 10°C almost invariably accelerated the browning.

Development of sliminess and decay. Hypocotyls of sprouts stored for a week at 0°C or 3 to 5 days at the higher temperatures frequently became slimy. The sliminess generally increased with temperature and duration of storage (Table 1), as observed earlier (7). When slight, the defect was not necessarily accompanied by the darkening noted earlier and, in some lots, seriously darkened sprouts were not slimy. Microscopic examination showed a sloughing of epidermal cells, but no obvious evidence of decay organisms.

Decay, as shown by a soft rot on part of the sprouts, also increased with duration of storage and temperature, as would be expected (Table 1). However, after 1 week at 0°C the increase was minimal even after 1 additional day at 10°C.

Development of musty odor. The typically musty odor generally associated with soft rot did not develop in sprouts held 1 week at 0°C, but was detectable in those held at 2.5°C; the odor became noticeable about 2 days at 5°C and by the third day at 10°C. When storage at 0, 2.5 or 5°C was followed by 1 day at 10°C, only the shortest storage periods (3, 2, and 2 days, respectively) did not induce the odor.

Growth and weight loss. We considered growth of the first true leaves to be objectionable when they emerged from between the cotyledons. This stage of growth was reached primarily after the sprouts had been transferred from 5 to 10°C or when the sprouts had been stored 2 days or longer at 10°C (Fig. 2). Elongation of the hypocotyl was minimal (2.5 mm or less) during 4 days at 10°C.

Weight loss from the sprouts, as stored in glass jars, never exceeded 3% or resulted in any perceptible wilting.

Overall quality. The overall quality rating summarizes all the sensory aspects of quality that we evaluated. Deterioration was more rapid with higher storage temperatures (Fig. 3). The rates of deterioration, which were 0.46, 0.72, 0.90, and 1.56 rat-
Temp Production\(\text{production}\) for range 0° to 5°C. 

Means based on 5 or 6 values. 

Data based on measurements made about 22 hr after the sprouts had been placed at constant temperature. 

For sprouts transferred from 0°, the rate was about 0.24 ± 0.08 \(\text{Q}_{10}\) for the range 0° to 5° (data not shown). 

Q,0 value cannot be attributed to microorganisms growing at 10°. Since these are initial rates of ethylene production, the high rate even though we obtained them from the same source. The symptoms of deterioration that we described were similar to those that Tajiri (7) saw, although we observed neither a wilting of the sprouts nor abscission of the cotyledons, which suggests that Tajiri held the sprouts under relatively dry conditions. 

Although the mung bean is a plant of tropical origin, and though there is evidence that mung beans are subject to chilling injury (CI) below 15°C (4), neither we nor Tajiri saw symptoms of CI. If mung bean sprouts were subject to CI, the rate of CO\(_2\) production should have remained substantially higher when they were transferred from a low temperature to 10°, in comparison to the rate for sprouts held continuously at 10°. Also, the longer the sprouts were at 0, 2.5, or 5°, the more rapidly they should have deteriorated after their transfer to 10°. However, the angles of the dotted lines in Fig. 3 (top) do not become progressively steeper as storage at each low temperature was prolonged. Perhaps imbibition of the seed in warm water reduced the impact of subsequent exposure to low temperature (6).

### Literature Cited