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HortScience 21(3):470–472. 1986.

A Systems Analysis of Postharvest Handling of Fresh Snap Beans

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Additional index words. *Phaseolus vulgaris*, packinghouse

Abstract. **The postharvest handling system of fresh market snap beans (*Phaseolus vulgaris* L. cv. Sprite) was analyzed to determine steps of greatest quality deterioration. A decrease in ascorbic acid concentration was the only consistent quality change noted between the arrival at the packinghouse and departure from the wholesale warehouse. Quality differences in percentage of fiber, percentage of seeds, color, hue angle, moisture, ascorbic acid, and sensory texture attributes observed in beans from different packinghouses suggest that cultural and harvesting factors are most critical. Short market shelf-life is a major limitation in marketing.**

Snap bean quality is affected by such preharvest factors as cultivar selection (18), planting date (12), row spacing and irrigation (2), and herbicide application (19). Maturity of the bean at harvest (14) is a major factor in snap bean quality. Mechanical harvesting increases bruising and accelerates quality deterioration (4). Application of sodium dehydroacetate retards discoloration of mechanically harvested beans (8). During storage, snap beans are susceptible to injury by excess air flow (3), chilling (20), SO_2, and CO_2 (6).

Less attention has been focused on fresh market beans than on beans for processing. Given the trend from processed (particularly canned) vegetables toward fresh produce, a concerted effort is required to understand the effects of various handling steps in the postharvest system on vegetable quality. Systems approaches have been used to study peach harvesting and handling in the orchard (7), handling of southern peas from the field to the processing plant (16), and marketing of tomatoes (1). Price/quality relationships have been developed for snap bean (9) and tomato (10) handling systems. The purpose of this study was to use the systems approach to isolate critical steps affecting snap bean quality during fresh-market postharvest handling.

The initial step in any systems approach is developing an outline of the overall system (16). From discussions with growers, county extension personnel, packers, wholesale distributors, retail produce managers, and personal observations by us, the current postharvest handling system for fresh-market snap beans is as follows. Snap beans (bush type) are mechanically or hand harvested and transferred to self-unloading trucks (usually 2.2 × 2.0 × 10 m). Up to 5 hr may be required to load a truck in the field, with delays of up to 2 hr in unloading at the packinghouse. At the packinghouse, the beans are conveyed through a series of machines that remove field debris and separate clusters. Sorting and grading is performed manually and the beans are packed into wire-bound boxes (usually signifying mechanically harvested beans). Most packinghouses have facilities for room cooling (5°C, 90% RH) prior to transport to a wholesale warehouse. Transport usually is confined to refrigerated trailers. Most beans are shipped from the packinghouse within a 12- to 24-hr period. Turnover of the beans at the wholesale warehouse (usually held at 3° to 6°) varies from 1 to 3 days. Beans are shipped to retail outlets, stored at 5°, and sold in 3 to 4 days or discounted for quick sale. At produce stands, however, beans may be held a week at ambient temperatures.

Snap bean quality was monitored through a defined postharvest system by removing 0.7- to 1.0-kg samples at each of the following steps: a) arriving at the packinghouse; b) leaving the packinghouse; c) arrival at the distribution warehouse; d) leaving simulated warehouse conditions (3 days at 5°C, 80% RH); and e) storage under either refrigerated (6 days at 5°, 80% RH), or room (6 days at 21°, 70% RH) conditions. Temperature and RH conditions were maintained in Environ-Room control chambers within ± 1° and ± 5% RH. Samples in steps a and b were cooled immediately in an ice chest but protected from contact with the ice and transported within 4 hr to a mobile laboratory (13) for sample analysis. All boxes were collected from step b at each of 3 packinghouses (designated R, S, and T) and consolidated at a single packinghouse for shipment to the distribution warehouse. Samples at step a were collected from the front, middle, and back of 8 trucks. One box packed from each truckload was used for sample collection for the subsequent steps (b–e).

On arrival at the mobile laboratory, each sample was divided into subsamples for the percentage of seeds, moisture, color, and shear measurements as described previously (17) and for ascorbic acid analysis (11) and blender fiber (5). Sensory evaluation was conducted on samples from steps d and e only using 9-point rating scales (17) with greater values corresponding to greater desirability. Statistical analysis was performed using the general linear model procedure for unbalanced models (15).

Although the snap beans sampled were of the same cultivar ('Sprite') and mechanically harvested on the same day within a 50-km radius of each other, there were detectable differences in the quality of the beans sampled (Table 1). Observed differences were attributed to maturity at harvest, evidenced by the reduced fiber content, the percentage of seeds, increased hue angle ($\tan^{-1}$ b/a) signifying an increase in green character, and increased moisture content of beans sampled from packinghouse T. Beans from S were lighter in color (higher L value) than those from the other houses. Although beans from R contained a significantly increased concentration of ascorbic acid, no significant difference was observed between packing houses R and T when ascorbic acid was expressed on a dry weight basis (data not shown). A sensory panel rated beans from R lower in textural quality than those from the other packers. No significant differences were detected in sensory color or flavor characteristics by the panel (data not shown).

The effects of handling on bean quality are shown in Table 2. No significant change

Received for publication 11 Mar. 1985. Snap bean samples were supplied by the Georgia Vegetable Company, Turner County Vegetable Growers, and Yates Packingshed. Appreciation is expressed to Sue Ellen McCullough and Bob Flewellen for technical assistance.The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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Table 1. Effect of sampling location on indices of maturity and quality for snap beans.

Packinghouse	Fiber (%)	Seeds (%)	Hunter color values: Lightness[x]	Hunter color values: Hue angle[y] (degrees)	Moisture (%)	Ascorbic acid (mg/100 g FW)	Sensory[z]: Mouthfeel	Sensory[z]: Texture
R	1.09 a[w]	8.0 a	39.3 a	123.4 a	90.8 a	11.7 a	3.9 a	3.4 a
S	1.09 a	7.1 a	40.9 b	123.3 a	90.8 a	10.0 b	4.9 b	4.4 b
T	0.89 b	4.8 b	38.5 a	124.1 b	91.8 b	10.2 b	4.7 ab	4.8 b

[z]Hedonic scale — Mouthfeel (1 = dislike extremely, 5 = neither like nor dislike, 9 = like extremely); and texture (0 = fibrous and tough, 8 = tender).
[y]$\tan^{-1}$ b/a calculated from Hunter a and b readings. Higher values signify greener hues, lower yellower.
[x]L reading in the Hunter color solid as measured by the Gardner XL-845 colorimeter. Higher readings signify lighter color.
[w]Means in a column separated by Duncan's multiple range test ($P \leq 0.05$).

Table 2. Effect of handling step on indices of quality for snap beans.

Step	Hunter color values: Lightness[z]	Hue angle[y] (degrees)	Moisture (%)	Ascorbic Acid (mg/100 g FW)
a) Arrive packinghouse	40.3 ab[x]	124.3 a	91.4 a	12.3 a
b) Leave packinghouse	39.9 c	124.3 a	91.2 a	12.1 a
c) Arrive warehouse	40.9 a	123.8 a	91.5 a	9.7 b
d) Leave warehouse	39.0 bc	123.9 a	91.8 a	8.3 b
e) Storage				
1) 6 days at 5°C	39.3 bc	122.4 b	91.8 a	5.9 c
2) 6 days at 21°C	39.1 bc	121.3 c	87.9 b	9.6 b

[z]L reading in the Hunter color solid as measured by the Gardner XL-845 colorimeter. Higher readings signify lighter color.
[y]$\tan^{-1}$ b/a calculated from Hunter a and b readings. Higher values signify greener hues, lower yellower.
[x]Means in a column separted by Duncan's multiple range test ($P \leq 0.05$).

in hue was observed before storage (step e), when yellowing (lower $\tan^{-1}$ b/a) occurred. Moisture content remained constant throughout handling, except during simulated retail storage under abuse conditions (step e2, 6 days at 21°C, 70% RH). Ascorbic acid concentration declined throughout handling with the greatest losses occurring during transport from the packinghouse to the warehouse (at night in a refrigerated trailer for 6 hr with air temperatures of 6°) and during storage. The high value obtained at step e2 was attributed to the reduced moisture content of the sample. When corrected for moisture concentration, the ascorbic acid value was lower but not significantly different from step e1. Sensory color, flavor, and texture differences were noted in all categories between step d (leaving warehouse) and steps e1 and e2 (simulated storage) (Table 3).

The only interactive effect of sampling location and handling step was observed for shear value. Samples from packinghouse T were more tender (shear 58–62 N) than samples from houses S (67–73 N) and R (68–77 N) during steps a–d. Beans from all 3 locations evidenced toughening only after 6 days at 21°C, 70% RH (data not shown). The increased shear values were attributed to moisture loss during storage (Table 2). Sensory evaluation revealed differences in handling steps for mouthfeel and texture (Table 3). Texture as the limiting quality characteristic observed in this study, but differences were not noted until the point of retail simulation.

The first objective of a systems approach is an analysis of the system to pinpoint the major problem handling steps. Subsequent research then is focused on evaluating alternate handling techniques in the context of the overall system. The data presented in this analysis indicate that minimal quality loss occurred in handling prior to leaving a wholesale warehouse. Therefore, the most critical step in the handling process before the retail outlet is in transportation from packinghouse to warehouse. The 25% loss in ascorbic acid observed during transport could be reduced by rapid precooling at packinghouses and improved air circulation or stacking patterns in the truck.

The differences observed in snap beans from the 3 locations were greater than those observed during handling. The data suggest that improvement in fresh market bean quality can be accomplished before arrival at the packinghouse and after leaving the wholesale warehouse. Further research should be directed at factors of cultural practices, harvesting, and storage techniques that prolong shelf life and enhance marketing flexibility.

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Table 3. Effect of handling step on sensory quality attributes.

Step	Color uniformity[z]	Green character[z]	texture[z]	General appearance[y]	Flavor[y]	Mouthfeel[y]	Overall acceptability[y]
d) Leave warehouse	5.9 a[x]	6.1 a	6.3 a	6.1 a	6.9 a	6.8 a	6.6 a
e) Storage							
1) 6 days at 5°C	5.2 a	5.6 a	5.4 b	5.6 a	5.7 b	5.6 b	5.4 b
2) 6 days at 21°C	4.3 b	3.9 b	3.7 c	3.8 b	3.3 c	2.8 c	3.3 c

[z]Descriptor scales (0–8): color uniformity (0 = not uniform, 8 = uniform): green character (0 = brown or offshade, 8 = bright green): and texture (0 = fibrous and tough, 8 = tender).
[y]Hedonic scales (1 = dislike extremely, 5 = neither like or dislike, 9 = like extremely).
[x]Means in a column separated by Duncan's multiple range test ($P \leq 0.05$).

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HortScience 21(3):472–474. 1986.

Changes in Ethylene, Acids, and Brown-core Development of 'Bartlett' Pears in Low-oxygen Storage

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Additional index words. *Pyrus communis*, malic acid, citric acid

Abstract. **Ethylene production of 'Bartlett' pears (*Pyrus communis* L.) was suppressed by 1% O_2 during storage at −1°C. Elevated CO_2 concentrations further suppressed ethylene production. Organic acids were retained at higher levels in fruits stored in 1% O_2 than in those stored in air, and elevated CO_2 concentrations in 1% O_2-enhanced acid retention. Both malic and citric acids decreased linearly during 8 days of ripening at 20° regardless of previous storage conditions. The suppression of ethylene production and the retention of organic acids implied a beneficial effect of elevated CO_2 in storage of 'Bartlett' pears at 1% O_2. Fruit stored in 1% O_2 at −1° for 4 months developed brown-core regardless of CO_2 levels in the storage, but the incidence of the disorder was enhanced when CO_2 level in the storage was ≥2%. This preliminary study indicated that 'Bartlett' pears grown in the Hood River district of Oregon could be stored at −1° for 4 months in 1% O_2 with CO_2 at <1.5% with a minimum risk of brown-core development.**

An increase in the fresh-market supply of 'Bartlett' pear fruit in recent years has led to a need for lengthening the storage period. 'Bartlett' fruit harvested at early maturity in California could be stored in 1% O_2 with CO_2 as high as 5% for 6 months with highly acceptable quality and without development of brown-core (6). Hansen and Mellenthin (8) also reported that 'Bartlett' pear fruit harvested at early maturity in Oregon developed only a slight (i.e., 2%) incidence of brown-core disorder after 4 to 5 months of storage in 1.1% O_2 plus 6.4% CO_2. One percent O_2 has been used for storage of 'd'Anjou' pear fruit in the Pacific Northwest with success, but due to the potential incidence of brown-core, the recommended CO_2 concentration in 1% O_2 has been ≤0.1%. This preliminary report attempts to determine the effects of CO_2 concentrations in 1% O_2 on ethylene production, organic acid retention, and brown-core development of 'Bartlett' pear fruit during or after a prolonged storage period.

Five uniform, mature 'Bartlett' trees were selected in an orchard at the Mid-Columbia Experiment Station, Hood River, Ore. When fruit reached optimum maturity (average flesh firmness of 84 N) on 8 Aug. 1983, about 120 fruit from each tree were harvested daily for 5 consecutive days. After each harvest, fruits were left in the orchard overnight to simulate a time lag in delivery to storage. Harvested fruits were well-randomized to eliminate the effect of harvesting period. Ten fruit lots were each placed into separate perforated polyethylene bags. Bagged fruits then were stored at −1°C in air for 14 days to simulate another time lag for commercial controlled-atmosphere (CA) storage. Eight bags of fruits per tree were transferred into each of 7 air-tight metal CA chambers (60 × 60 × 90 cm) located in a walk-in cooler at −1°. One chamber was supplied with air, and the other 6 chambers with 1% O_2 plus 0%, 1%, 1.5%, 2.0%, 2.5%, and 3% CO_2 by mixing O_2 (breathing grade), N_2, and 15% CO_2 in N_2. The CO_2 in one chamber was scrubbed by using hydrated lime (0.5 kg per 10 kg fruit) and the CO_2 concentration was maintained at about 0.03% or less throughout the storage period. The flow rate was about 50 ml·min^{-1}. The desired gas mixture was maintained within ±0.2% throughout 4 months of storage. Concentrations of O_2 and CO_2 were monitored daily and ethylene every other day by gas chromatography (3, 4). Relative humidity in each chamber was not controlled or monitored.

After 4 months of storage, fruit were returned to air and held at −1°C for 1 week. Five bags of fruit (50 fruit each) per tree per treatment were halved longitudinally and evaluated for brown-core. The symptom of the brown-core disorder was dry, pithy flesh, with occasional development of cavities from 1 to 5 mm in diameter. The injured areas did not discolor intensively and were not always confined to the core. Depending on the severity of the disorder, each fruit was classified as clear, very slight, slight, moderate,

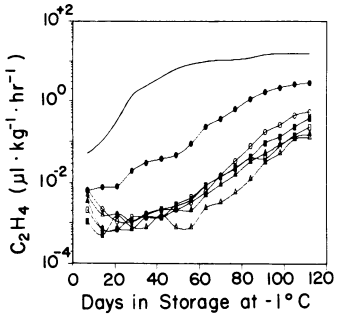

Fig. 1. Ethylene production of 'Bartlett' pears stored in 1% O_2 with CO_2 concentrations at 0% (●), 1% (○), 1.5% (■), 2% (□), 2.5% (▲), and 3% (△); and in air (—) at −1°C during 4 months of storage.

Received for publication 20 Mar. 1985. Oregon State Agricultural Experiment Station Technical Paper No. 7478. This study was supported by the Washington State Tree Fruit Research Commission. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

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