Quality of Green Beans, Bell Peppers and Spinach Stored in Polyethylene Bags

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ABSTRACT

Quality attributes of packaged and unpackaged vegetables generally decreased nonlinearly during storage at 10°C or 20°C, and most of the decrease was greater at 20°C than at 10°C. Packaging reduced weight loss of green beans and spinach kept at 20°C; and reduced chlorophyll loss of green beans at 10°C and of spinach at 20°C. Ascorbic acid (vitamin C) benefited by packaging of green beans and spinach kept at 10°C. Packaging had an effect on thiamin (vitamin B_1) of only spinach held at 10°C and 20°C, and had no effect on riboflavin (vitamin B_2). Loss of these quality attributes appears to be enhanced with water loss.

INTRODUCTION

BENEFITS of low temperatures and high relative humidity during handling and storage of fresh produce are recognized and appropriate conditions are recommended by Hardenburg et al. (1986). Lower temperatures have been shown to better maintain ascorbic acid in asparagus (Scott and Kramer, 1949), kale (Ezell and Wilcox, 1959), green beans, peas, and spinach (Zacharias, 1962), and β- carotene in kale (Ezell and Wilcox, 1962). High relative humidity also has been shown to maintain vitamins as indicated by the greater loss of ascorbic acid content and β-carotene in kales that dried more rapidly (Ezell and Wilcox, 1959, 1962). High relative humidity is attained for some produce by packaging, but the optimum temperature is not maintained, particularly at the retail level. This study was undertaken to determine the effect of packaging and warm temperature on weight loss and contents of chlorophyll, ascorbic acid (vitamin C), thiamin (vitamin B_1), and riboflavin (vitamin B_2) of vegetables.

MATERIALS & METHODS

GREEN BEANS (*Phaseolus vulgaris* L.), bell peppers (*Capsicum annum* L.), and spinach (*Spinacea oleracea* L.), were obtained from a local produce distribution center, sorted for freedom of defects and uniformity, and separated into sublots for three replicates of packaged and unpackaged samples at each temperature-time treatment. For packaged samples, the vegetables were placed in a 20 cm × 8 cm × 50 cm, 1 mil polyethylene bags with fifty-six 6-mm diameter holes. The nonpackaged vegetables were placed in an open tray. The samples were placed at 10°C or 20°C for the time period indicated under Results.

The following quality attributes were monitored. Weight was measured to determine loss with time. Wilting condition and color were determined subjectively by the authors and scored from 4 to 1, with 4 = fresh, no wilting or color loss, 3 = slight wilting or color loss, 2 = moderate wilting or color loss, and 1 = severe wilting or color loss. Chlorophyll content was determined as described by Arnon (1949). Vitamins B_1, B_2, and C were determined by high-performance liquid chromatography as described elsewhere (Watada, 1982; Watada and Tran, 1985, 1987).

Data were statistically analyzed using the general linear models procedure of the Statistical Analysis System, release 82.3. The model consisted of two class independent effects (packaging and storage temperature) and one continuous independent effect (duration of storage) arranged as a factorial completely randomized design repeatedly measured over time. For each dependent variable of each vegetable, regression equations describing the response to duration of storage were calculated separately for the four packaging*temperature combinations. However, to facilitate comparisons of the regression coefficients of these lines, a common model was determined by analyzing the data for all lines simultaneously with analysis of covariance and noting the class*continuous effect interactions. A quadratic response was considered to be the maximum polynomial degree to have biological significance. The simple effect comparisons among these regression lines were then made by noting the class*continuous effect interaction in an analysis of covariance using only the data for the two lines being compared.

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RESULTS & DISCUSSION

WEIGHT LOSS during storage differed with vegetable, packaging, and temperature. The pattern of weight loss was nonlinear for green beans (Fig. 1) and spinach (Fig. 3), and linear for bell peppers (Fig. 2). In green beans, the loss in unpackaged 20°C samples was greater than that in packaged 20°C or unpackaged 10°C samples (Table 1). Weight loss of packaged 10°C samples did not differ significantly from that of packaged 20°C or unpackaged 10°C samples. Bell peppers lost the least weight among the vegetables, with the maximum loss being 10% in the unpackaged 20°C samples. All bell peppers lost weight, but the loss was not affected by packaging or temperature. Spinach lost the most weight among the vegetables with the maximum being approximately 65% in the unpackaged 20°C samples by the third day of storage. Weight loss of these samples differed from that of packaged 20°C samples in both the linear and quadratic changes, and of the unpackaged 10°C samples in the linear changes (Table 1). Packaged 10°C samples lost less weight than the packaged 20°C or the unpackaged 10°C samples, and was significant in the linear segment of the change.

The wilting condition did not always correlate with weight loss. Unpackaged green beans wilted more than packaged samples at 20°C (Table 2), whereas no differences were noted between packaging at 10°C, an observation similar to the weight loss. All green bean samples wilted more at 20°C than at 10°C, but the same differences were not noted with weight loss of packaged samples. Wilting of bell pepper, was greater at 20°C than at 10°C, and in the unpackaged sample than the packaged sample at 20°C. In contrast, the differences in weight loss among these treatments were not significant. In spinach, the wilting condition was greater at the higher temperature and in the unpackaged samples, a change similar to that of weight loss. Wilting and weight loss were extensive in spinach and because of the large changes, the correlation between wilting condition and weight loss is readily apparent.

Chlorophyll content of all vegetables decreased in a nonlinear pattern as supported by quadratic equations of the regression (Table 1). With green beans (Fig. 1), the packaged 10°C

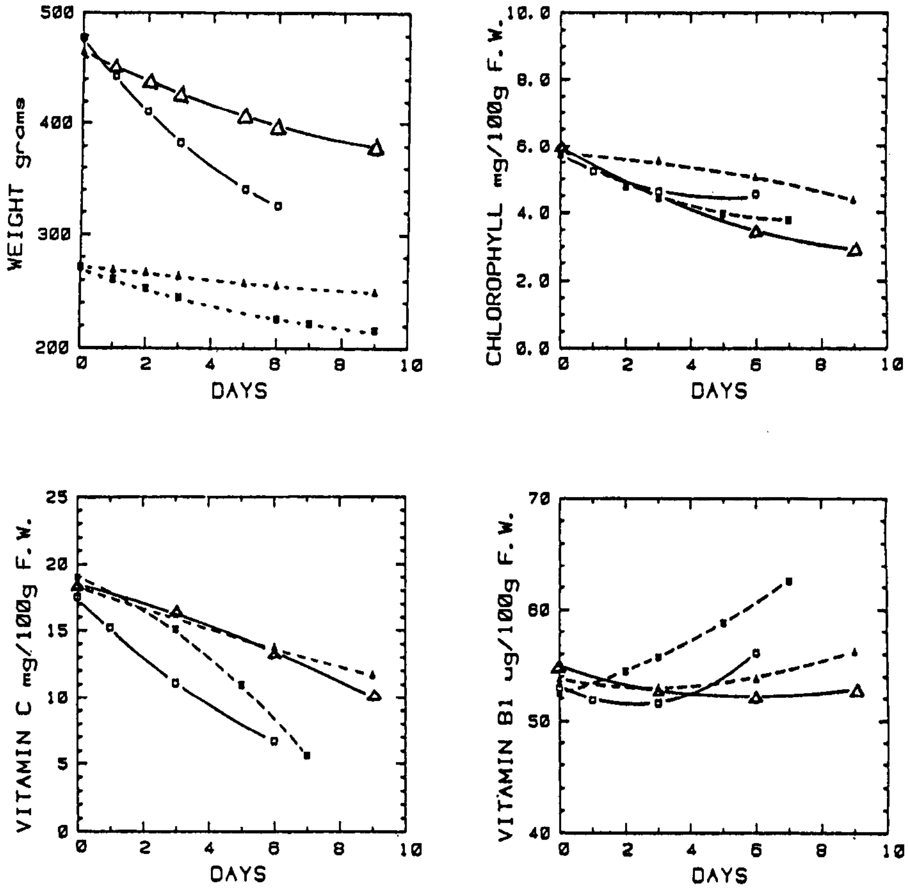

Fig. 1— Predicted weight, and contents of chlorophyll, vitamin C and vitaminB_1 in green beans stored at 10°C packaged (–▲–) or unpackaged (-△-) or at 20°C packaged (–■–) or unpackaged (-□-). Each predicted point was derived from data of three replicates.

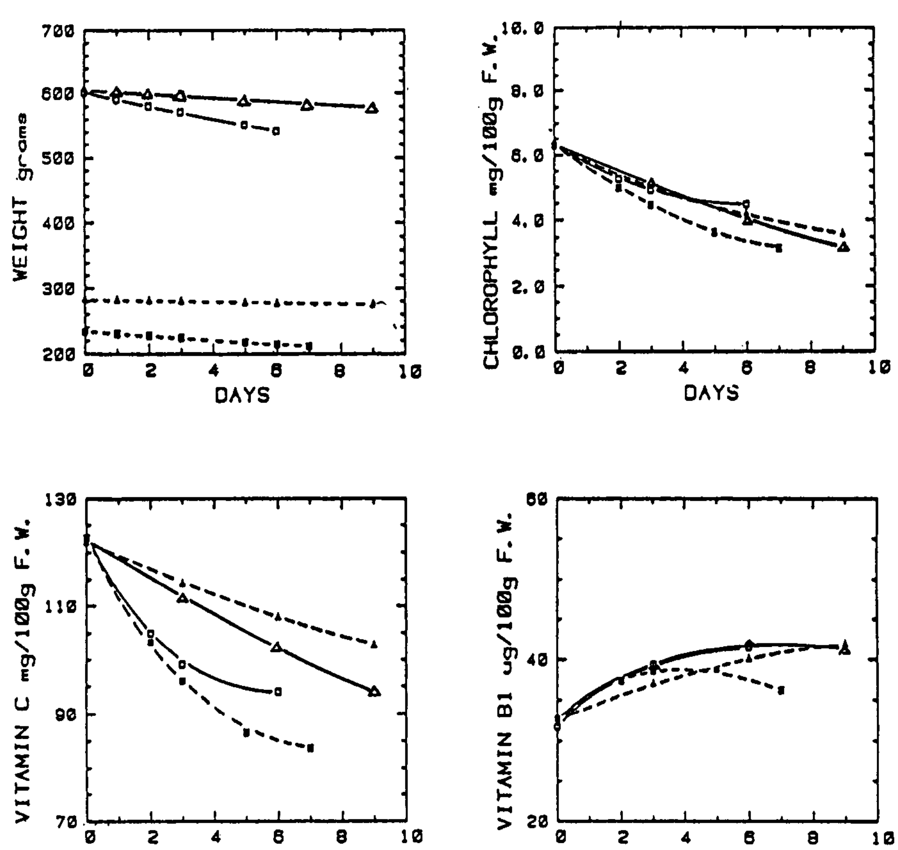

Fig. 2— Predicted weight, and contents of chlorophyll, vitamin C and vitamin B_1 in bell peppers stored at 10°C packaged (–▲–) or unpackaged (-△-) or at 20°C packaged (–■–) or unpackaged (-□-). Each predicted point was derived from data of three replicates.

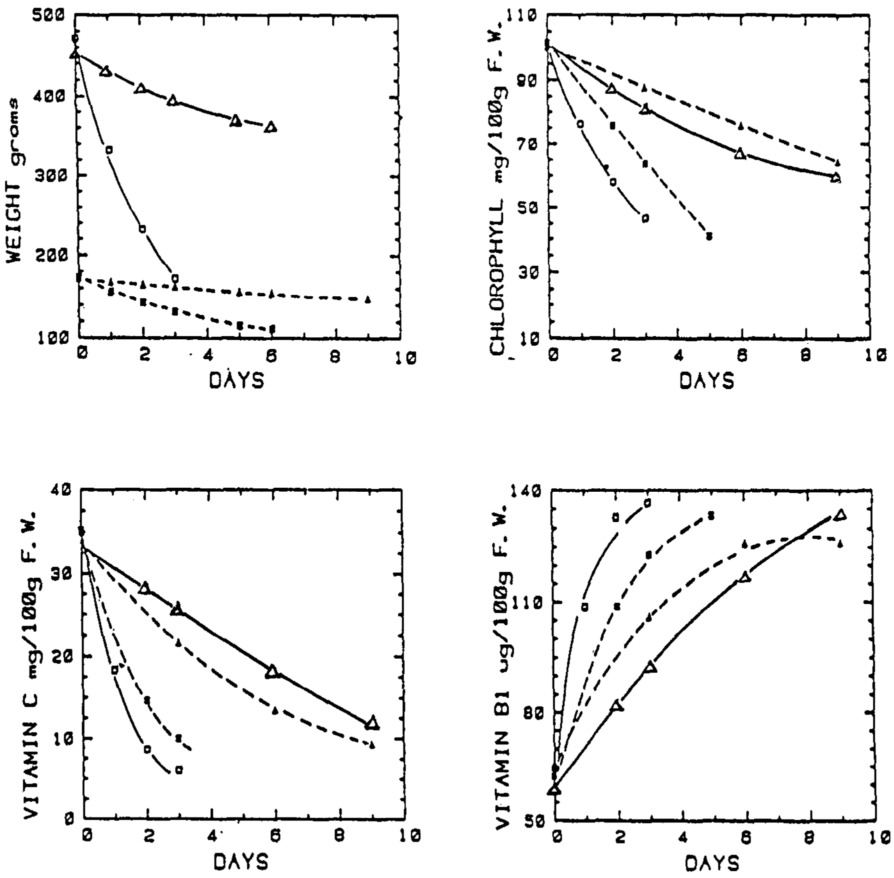

Fig. 3— Predicted weight, and contents of chlorophyll, vitamin C, and vitamin B_1 in spinach stored at 10°C packaged (-▲-) or unpackaged (-△-) or at 20°C packaged (-■-) or unpackaged (-□-). Each predicted point was derived from data of three replicates.

samples lost the least amount of chlorophyll as compared to the other treatments. This treatment differed from the packaged 20°C treatment in the linear segment of change, and from the unpackaged 10°C treatment in the quadratic segment (Table 1). The unpackaged samples of green beans at 10°C lost more chlorophyll than those at 20°C for some unknown reason. Packaging had no effect on chlorophyll of samples at 20°C. In bell pepper (Fig. 2), the only differences among treatments were between unpackaged 10°C and 20°C samples. Chlorophyll content of spinach (Fig. 3) was approximately 15 times greater than that of the other two vegetables. Loss was greater at 20°C than at 10°C, and in unpackaged samples than in packaged samples at 20°C. Packaging had no effect on spinach samples at 10°C.

Visual color changed during storage with spinach losing the most color at both temperatures, and bell peppers being intermediate at 20°C (Table 3). Among the treatments the unpackaged 20°C samples lost the most color, and the loss was slight to moderate in green beans, and moderate to severe in bell peppers and spinach at the end of their respective storage periods. Color loss of all vegetables was greater at 20°C than at 10°C, and in nonpackaged sample than in packaged samples at 20°C. At 10°C, only spinach showed a difference between packaged and unpackaged samples. The differences among treatments in visual color changes were not always supported by the chlorophyll data; and the lack of support was not specific with any treatment or vegetable.

Vitamin C content of all vegetables decreased nonlinearly during storage (Fig. 1, 2, and 3; Table 1). With green beans (Fig. 1), the unpackaged 20°C samples lost vitamin C most rapidly among the treatments, with 63% lost by the sixth day. The packaged 20°C sample lost 54% by the sixth day; whereas both packaged and unpackaged samples at 10°C lost only 25% of the total content. The regression equations of packaged and unpackaged samples at 10° and 20°C differed significantly in the linear changes (Table 1). The average loss by the 12th day was calculated to be 50% greater in the unpackaged than the packaged samples at 10°C.

The initial vitamin C content of bell peppers was 122 mg/100g fresh weight, which was approximately three and six times greater than that in spinach and green beans, respectively. Vitamin C content of bell peppers decreased more rapidly at 20°C than at 10°C (Fig. 2, Table 1), with the average loss by the fourth day being 25% at 20°C and 10% at 10°C. Packaging had no effect on vitamin C retention in bell peppers.

Vitamin C content of spinach decreased sharply during storage (Fig. 3). By the third day at 20°C unpackaged samples lost 83% of its content, which was not significantly different from that of the 20°C packaged samples, but was greater than the 22% of unpackaged samples at 10°C. At 10°C, the packaged samples lost more vitamin C (35%) than the unpackaged samples (22%) for some unknown reason, but the loss was less than that (71%) of the packaged samples at 20°C. Spinach maintained salable quality for 9 days at 10°C, at which the vitamin C had dropped by 73% and 64% in the packaged and unpackaged samples, respectively.

Vitamin B_1 generally increased in a nonlinear pattern during storage. With green beans (Fig. 1), the pattern of change of packaged 20°C samples appears to be different from that of other treatments, as indicated by the graph (Fig. 1) and regression equations, but the statistical analysis indicated that the differences were not significant (Table 1). Vitamin B_1 of bell peppers also were not affected by temperature or packaging as noted with the green beans (Fig. 2). In spinach, the vitamin B_1 content increased sharply during storage (Fig. 3). The increase in the unpackaged 20°C samples was greater than that of packaged 20°C or unpackaged 10°C samples. This finding of having a larger increase at a more undesirable holding treatment is puzzling. At 10°C, the increase in packaged samples was greater than the unpackaged samples.

Table 1—Regression equations of quality changes of packaged or unpackaged green beans, bell peppers, and spinach held at 10° or 20°C

Vegetable	Packaged	°C	Regression equation	Significance of differences: Packaged 20°C	Significance of differences: Unpackaged 10°C
Green beans	Yes	10	Weight[a] = 272.6 − 3.14 day + 0.06 day^2	n.s.	n.s.
	Yes	20	Weight[a] = 271.1 − 10.14 day + 0.44 day^2	–	–
	No	10	Weight[a] = 465.1 − 14.31 day + 0.53 day^2	–	–
	No	20	Weight[a] = 479.4 − 38.68 day + 2.20 day^2	L[d]	L
	Yes	10	Chlorophyll[b] = 5.85 − 0.070 day − 0.011 day^2	L	Q[e]
	Yes	20	Chlorophyll[b] = 5.72 − 0.544 day − 0.038 day^2	–	–
	No	10	Chlorophyll[b] = 5.90 − 0.597 day − 0.029 day^2	–	–
	No	20	Chlorophyll[b] = 5.71 − 0.507 day − 0.569 day^2	n.s.	L
	Yes	10	Vit. C[b] = 18.40 − 0.83 day + 0.010 day^2	n.s.	L
	Yes	20	Vit. C[b] = 18.96 − 0.85 day − 0.150 day^2	–	–
	No	10	Vit. C[b] = 18.56 − 0.67 day − 0.03 day^2	–	–
	No	20	Vit. C[b] = 17.53 − 2.47 day + 0.11 day^2	L	L
	Yes	10	Vit. B_1 c = 53.76 − 0.50 day + 0.087 day^2	n.s.	n.s.
	Yes	20	Vit. B_1 c = 52.46 + 0.83 day + 0.088 day^2	–	–
	No	10	Vit. B_1 c = 54.95 − 0.95 day + 0.080 day^2	–	–
	No	20	Vit. B_1 c = 53.00 − 1.45 day + 0.329 day^2	n.s.	n.s.
Bell Peppers	Yes	10	Weight = 283.6 − 0.89 day	n.s.	n.s.
	Yes	20	Weight = 233.0 − 3.16 day	–	–
	No	10	Weight = 581.7 − 0.85 day	–	–
	No	20	Weight = 600.9 − 9.78 day	n.s.	n.s.
	Yes	10	Chlorophyll = 6.32 − 0.456 day − 0.017 day^2	n.s.	n.s.
	Yes	20	Chlorophyll = 6.28 − 0.741 day − 0.042 day^2	–	–
	No	10	Chlorophyll = 6.41 − 0.484 day − 0.015 day^2	–	–
	No	20	Chlorophyll = 6.28 − 0.622 day − 0.053 day^2	n.s.	Q
	Yes	10	Vit. C = 121.85 − 2.68 day + 0.062 day^2	L	n.s.
	Yes	20	Vit. C = 122.52 − 11.30 day + 0.823 day^2	–	–
	No	10	Vit. C = 122.24 − 3.718 day + 0.063 day^2	–	–
	No	20	Vit. C = 122.67 − 10.92 day + 1.023 day^2	n.s.	Q
	Yes	10	Vit. B_1 = 32.76 + 1.65 day + 0.069 day^2	n.s.	n.s.
	Yes	20	Vit. B_1 = 32.69 + 3.07 day − 0.367 day^2	–	–
	No	10	Vit. B_1 = 32.90 + 2.59 day − 0.180 day^2	–	–
	No	20	Vit. B_1 = 31.73 + 3.46 day − 0.306 day^2	n.s.	n.s.
Spinach	Yes	10	Weight = 170.6 − 3.20 day + 0.08 day^2	L	L
	Yes	20	Weight = 172.8 − 17.51 day + 1.19 day^2	–	–
	No	10	Weight = 453.6 − 24.69 day + 1.60 day^2	–	–
	No	20	Weight = 471.0 − 158.22 day + 19.4 day^2	L, Q	L
	Yes	10	Chlorophyll = 99.95 − 4.15 day + 0.021 day^2	L	n.s.
	Yes	20	Chlorophyll = 101.11 − 13.18 day + 0.225 day^2	–	–
	No	10	Chlorophyll = 101.65 − 7.94 day + 0.364 day^2	–	–
	No	20	Chlorophyll = 101.39 − 26.61 day + 3.437 day^2	L, Q	L, Q
	Yes	10	Vit. C = 33.77 − 4.73 day + 0.224 day^2	L	Q
	Yes	20	Vit. C = 35.02 − 13.87 day + 1.844 day^2	–	–
	No	10	Vit. C = 33.53 − 2.71 day + 0.035 day^2	–	–
	No	20	Vit. C = 35.17 − 20.37 day + 3.56 day^2	n.s.	L, Q
	Yes	10	Vit. B_1 = 65.49 + 16.81 day − 1.12 day^2	n.s.	L, Q
	Yes	20	Vit. B_1 = 62.32 + 29.26 day − 3.01 day^2	–	–
	No	10	Vit. B_1 = 58.68 + 12.81 day − 0.05 day^2	–	–
	No	20	Vit. B_1 = 64.65 + 54.19 day − 10.06 day^2	L	L

[a] Weight in grams.
[b] Chlorophyll and vitamin C content in mg/100g fresh weight.
[c] Vitamin B_1 content in μg/100g fresh weight.
[d] Difference significant in the linear (L) segment of regression at $P<0.05$.
[e] Difference significant in the quadratic (Q) segment of regression at $P<0.05$.

Vitamin B_2 contents of the three vegetables changed minimally during storage, and were not affected by packaging or temperature (data not shown). The initial contents were 54 and 170 μg/100g fresh weight for bell peppers and spinach, respectively, which are approximate values reported by Haytowitz and Matthews (1986). The content in green beans was 40 ug/100 g fresh weight, which is less than 50% of the value reported in the handbook. The reason for such a low value is not known.

Packaging and storage temperature of 10°C generally maintained the various quality attributes better than unpackaged condition and/or a higher storage temperature of 20°C. The degree of benefit differed with vegetables and quality attributes. Temperature had a greater effect than packaging, and the benefits of packaging were greater at 20°C than 10°C. If the storage temperature was lowered to 0°C, the benefits of packaging probably would be minimal. However, temperatures during wholesale and retail handling generally is 10°C or higher, so benefits of packaging can be recognized.

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Table 2—Wilting condition[a] of green beans, sweet peppers, and spinach that are unpackaged or packaged in 1 mil perforated bag and stored at 10° or 20°C

			Days of storage					
Vegetab	Packaged	°C	0	2	3	5	6	8
Green bean	Yes	10	4.0	4.0	4.0	3.7	3.6	3.4
	Yes	20	4.0	3.6	3.3	2.0	1.6	—
	No	10	4.0	3.9	3.8	3.5	3.4	3.3
	No	20	4.0	2.9	2.4	1.5	1.1	—
Bell peppers	Yes	10	4.0	4.0	4.0	3.7	3.6	3.3
	Yes	20	4.0	3.8	3.3	2.2	1.8	—
	No	10	4.0	4.0	4.0	3.7	3.6	3.3
	No	20	4.0	3.3	2.5	1.7	1.3	—
Spinach	Yes	10	4.0	3.8	3.7	3.5	3.4	3.2
	Yes	20	4.0	2.8	2.3	1.2	—	—
	No	10	4.0	3.7	3.4	3.0	2.8	2.4
	No	20	4.0	1.3	0.3	—	—	—

[a] 4 = no wilting (fresh); 3 = slight wilting; 2 = moderate wilting; 1 = severe wilting

Table 3—Visual color[a] of green beans, bell peppers, and spinach that are unpackaged or packaged in 1 mil perforated film bag and stored at 10° or 20° C

			Days of storage					
Vegetable	Packaged	°C	0	2	3	5	6	8
Green beans	Yes	10	4.0	3.9	3.8	3.5	3.4	3.3
	Yes	20	4.0	3.6	3.4	3.2	3.0	—
	No	10	4.0	3.9	3.8	3.7	3.6	3.4
	No	20	4.0	3.6	3.4	2.7	2.4	—
Bell peppers	Yes	10	4.0	3.9	3.8	3.7	3.6	3.3
	Yes	20	4.0	3.6	3.3	2.6	1.9	—
	No	10	4.0	4.0	4.0	3.7	3.6	3.5
	No	20	4.0	3.3	2.5	1.7	1.3	—
Spinach	Yes	10	4.0	4.0	4.0	3.6	3.4	3.3
	Yes	20	4.0	3.0	2.3	0.8	—	—
	No	10	4.0	3.6	3.3	2.7	2.4	2.0
	No	20	4.0	2.0	1.3	—	—	—

[a] 4 = fresh color; 3 = slight loss of color; 2 = moderate loss of color; 1 = severe loss of color.

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NITRATE/NITRITE ANALYSIS AND FOOD LEVELS. . .From page 1636

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