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Persistent-Green Color Snap Beans (*Phaseolus vulgaris* L.): Color-related Constituents and Quality of Cooked Fresh Beans¹

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Abstract. Evaluations of cooked fresh beans showed that the persistent-green color (PC) cv., Custer, was darker, greener, and less yellow than the normal-green cv., Canyon. Persistent-green color lines XIda 71-2081 and XIda 267-4 were intermediate between the 2. Chlorophyll concentrations were higher in all PC lines than in the normal-green cultivar but the ratio of chlorophyll a/b was lower. Chlorophyll content was significantly correlated with Gardner color values and with visual color scores. No color values correlated with pheophytin or carotene content.

XIda 71-2081 had the highest work-to-shear values, % seed, % fiber, and highest panel scores for fibrousness. Whether the higher values were attributable to genetic controls or to a difference in maturity was not determined in this study. Little sloughing was observed. All cultivars had a slightly to moderately full, natural flavor. The PC beans were equal or superior to the normal-green cultivar in all measured quality characteristics with 'Custer' showing the most promise.

The acceptance or rejection of vegetables on the basis of color or other quality attributes has implications not only for agriculture and the food industry but also for the nutritional well-being of the population. Since color and appearance factors are the only quality attributes that can be appraised at the time of purchase (11), the development of vegetable cultivars with an especially attractive appearance and satisfactory culinary quality should increase consumer appeal. Increased vegetable consumption will benefit both the industry materially and the consumer nutritionally. The desirability of including quality and nutritive value in plant breeding programs has been emphasized by Stevens (17).

The importance of color, texture, and other quality attributes to consumers and to institutional buyers of green beans has been pointed out by Hard et al. (8) and Fox and Kramer (5). Some new lines of snap beans developed at the Twin Falls Branch Experiment Station hold particular promise with respect to increasing consumer appeal. These beans have an attractive, uniform, persistent-green color (PC) in both pod and seed coat plus the additional advantages of good yield of seed, good germination rate, and resistance to seed-borne mosaic and curly top diseases (2). Mayland and Dean (14) reported that differences in color of raw pods assessed by visual techniques among the PC and normal beans did not correlate with the content of total chlorophyll. They suggested that the chlorophyll concn varied in internal vs. external tissues. However, this observation is not in agreement with the findings of Hoffman and Kanapaux (9) who reported that visual color intensity of raw pods was highly correlated with chlorophyll content in the 10 cultivars of snap beans that they studied.

According to Mackinney and Little (12), pigments responsible for color in snap beans include not only the chlorophyll but also carotenoids and occasionally flavonoids. Color changes in green vegetables are probably due to the conversion of chlorophyll to pheophytin (13). Dietrich et al. (3) stated that neither the absolute amount of chlorophyll nor the ratio of chlorophyll a to b provided as much information about color changes in green vegetables during frozen storage as did

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⁴Lestlie Sea Salt Plain with MgCO₃ (NaCl₂ of the highest purity with 0.5% MgCO₃ added as an anticaking agent).

the ratio of chlorophyll to pheophytin.

According to Fox and Kramer (5), the quality factors in beans which influence appearance also influence texture and flavor. Changes in one are concomitant with changes in the others at least during the maturation period.

This study was undertaken to determine the relationships between color of snap beans and color-related constituents, to assess the content of ascorbic acid, carotene, chlorophyll, and pheophytin, and to evaluate certain quality characteristics of importance in the market.

Materials and Methods

The snap beans were grown at the Twin Falls, Idaho Branch Experiment Station. The pods were harvested from 3 PC lines, Xida 71-2081, Xida 267-4, and 'Custer', and one normal-green Tendercrop type, 'Canyon', 71 days after planting. They were then graded to sieve size 5 and refrigerated overnight prior to air freighting to Moscow where they were stored at 5°C for an additional 1 to 8 days before evaluation.

Preparation. The beans were washed, trimmed, and cut into 3.2-cm pieces for Portions I and III and into 6.4-cm pieces for Portion II. All beans were cooked in a 1.2% salt⁴ solution for 19 min. For Portions I and II, the beans were cooled under running water and placed between the folds of a towel until tested. Portion III was evaluated hot.

Measurements on Portion I. Color attributes of the samples were measured in triplicate as *Rd* (dark to light), *-a* (greenness), and *+b* (yellowness) values on a Gardner Color Difference Meter having a 3.7 cm aperture and standardized with an olive-green Gardner color tile No. CDY 0067 (*Rd* = + 8.6; *a* = -1.2; *b* = + 20.3). Although *-a* and *b* are not absolutely equivalent to "greenness" and "yellowness", respectively, they are correlated to some degree with these color sensations for normal vision.

The ratios of $\frac{-a/b}{Rd}$ (greenness/yellowness) and of $\frac{-a/b}{Rd}$ (a function which includes all aspects of color) were computed. The cooked beans were placed in layers to completely fill a glass-bottom sample cup 37 mm deep. Since this was a nondestructive test, the same beans were used for assay of carotene, chlorophyll, pheophytin, and ascorbic acid.

The carotenes were determined on two 20-g portions of cooked beans according to a modification of A.O.A.C. method 39.014 (10), i.e. the first extraction was made with 100 ml of acetone rather than with a mixture of acetone and hexane. The optical density (O.D.) was measured at 440 nm with a Beckman D. U. Spectrophotometer. The concn was calculated from a standard curve prepared with pure beta-carotene and reported as $\mu\text{g}/100$ g fresh wt basis. Total chlorophyll, chlorophyll a (yellow-green pigment), chlorophyll b (blue-green pigment), and chlorophyll-plus-pheophytin were determined on the acetone

extract according to the A.O.A.C. procedure (10) as modified by Sweeney and Martin (19). Optical density was read at 558, 642.5, 660, and 665 nm. Calculations were based on the A.O.A.C. formulas with the acetone correction factor of Sweeney and Martin as follows:

- (1) Total chlorophyll (mg/L) = $(8.69) (A_{660}) + (20.50) (A_{642.5}) \frac{A_{558}}{0.0068}$
- (2) Chlorophyll + pheophytin (mg/L) = $\frac{A_{558}}{0.0068}$
- (3) Pheophytin (mg/L) = (1) - (2)
- (4) % Chlorophyll retained = $\frac{(1)}{(2)} \times 100$
- (5) Chlorophyll a (mg/L) = $(12.11) (A_{660}) - (0.95) (A_{642.5})$
- (6) Chlorophyll b (mg/L) = $(21.47) (A_{642.5}) - (3.43) (A_{660})$
- (7) $\text{mg}/100 \text{ g} = \frac{\text{mg/L}}{1000 \text{ ml}} \times \frac{100 \text{ g}}{\text{g sample}}$

No chlorophyll determinations were made on fresh beans because the assumption in the calculations is that no pheophytin is present in fresh beans. Pheophytin content was considered to be the difference between total chlorophyll and chlorophyll-plus-pheophytin.

Ascorbic acid was determined on two 50-g samples of beans according to the method of Roe and Osterling (16). pH was measured on a portion of the acetone extract and on the cooking water. Moisture assays were carried out in duplicate on 5-g samples of beans in a vacuum oven (10). Sloughing and splitting of pods were determined in duplicate on 20 pieces of bean according to the method described by Van Buren et al. (20). Amounts of sediment under 6 ml indicate little or no sloughing.

Measurements on Portion II. Shear-compression was measured in duplicate on 80-g samples of beans using an Instron Universal Testing Machine. The pieces were placed in an Allo CS-1 Standard Shear-Compression Test Cell perpendicular to the grids. During the operation, a series of 10 parallel shear blades 3.2 mm thick first compressed and then sheared the sample in the cell box. To assure a precise mesh with the cell's shear grid, each blade is automatically aligned by guide slots within the cell. Maximum force was read directly from the graph. The material used for each Instron test was then quantitatively transferred from the test cell assembly to a plastic container and frozen until used for fiber determinations.

Fiber determinations were made on the thawed samples according to the quick method described by Guyer and Kramer (7). The mean wt of the dry residue was taken as the wt of fiber in the sample.

Percent seed was determined in duplicate by weighing the

Table 1. Means, standard deviations, and significance of cultivar differences for color values and color-related constituents in snap beans.

| Line or cultivar | Gardner color values ^Z | | | | | Taste panel color score ^Y | Chlorophyll | | | | Retention % | Pheophytin mg/100g | Carotene $\mu\text{g}/100\text{g}^X$ |
|------------------|-----------------------------------|-----------|-----------|-------------|-------------------|--------------------------------------|---------------|-----------|-----------|-------|-------------|--------------------|--------------------------------------|
| | <i>Rd</i> | <i>-a</i> | <i>+b</i> | <i>-a/b</i> | $\frac{-a/b}{Rd}$ | | Total mg/100g | a mg/100g | b mg/100g | a/b | | | |
| Custer | 9.4a ^W | 9.2a | 17.2a | 0.53A | 0.057a | 4.3a | 5.09A | 3.72A | 1.37a | 2.72a | 76.96 | 1.53 | 416 |
| Xida 267-4 | 9.8a | 7.9b | 17.9ab | 0.44B | 0.045ab | 4.2a | 4.79A | 3.52A | 1.27a | 2.78a | 72.32 | 1.84 | 428 |
| Xida 71-2081 | 10.7ab | 8.4ab | 17.5a | 0.48AB | 0.046ab | 4.0ab | 4.78A | 3.51A | 1.28a | 2.74a | 76.05 | 1.54 | 361 |
| Canyon | 11.1b | 7.8b | 19.1b | 0.41B | 0.037b | 3.1b | 3.96B | 2.96B | 1.00b | 2.96b | 72.31 | 1.52 | 294 |
| S.D. | 1.0 | 0.9 | 1.0 | 0.06 | 0.009 | 0.6 | 0.49 | 0.34 | 0.15 | 0.12 | 4.78 | 0.35 | 90 |

^ZA higher value for *Rd* indicates a lighter color. A higher value for *-a* indicates a greener product. A higher value for *b* indicates a yellower product.

^YRange: 5, bright green, to 1, dark, brownish green.

^X0.6 μg of beta-carotene = 1 I.U. of vitamin A (15).

^WMean separation within columns by Duncan's multiple range test at the 1% level with capitals; at 5%, lower case; non-significant, no letters.

Table 2. Simple correlation coefficients between color values and color-related constituents in 4 snap bean cultivars.

| Color-related constituents | Gardner color values | | | | | Taste panel color score |
|----------------------------|----------------------|-------|---------|--------|-------------------|-------------------------|
| | Rd | -a | +b | -a/b | $\frac{-a/b}{Rd}$ | |
| Total chlorophyll | -0.72* | 0.60* | -0.73** | 0.75** | 0.84** | 0.81** |
| Chlorophyll a | -0.74* | 0.59* | -0.72** | 0.75** | 0.84** | 0.80** |
| Chlorophyll b | -0.67* | 0.59* | -0.75** | 0.75** | 0.81** | 0.84** |
| Chlorophyll a/b | 0.31 | -0.37 | 0.57* | -0.49 | -0.46 | -0.68** |
| % Chlorophyll retention | -0.33 | 0.59* | -0.47 | 0.67** | 0.61* | 0.31 |
| Pheophytin | 0.02 | 0.41 | 0.16 | -0.41 | -0.30 | -0.02 |
| Carotene | -0.16 | 0.37 | -0.18 | 0.35 | 0.32 | 0.37 |

*Correlation significant at the 5% level; **significant at the 1% level.

seed from 100-g samples of cooked beans.

Appraisals on Portion III. A panel of 8 trained, experienced judges evaluated the 4 coded samples for color, firmness, fibrousness, and flavor (7, 18). Higher scores indicate a greater degree of the characteristic was present.

Statistical design. The experimental design was 4 x 4 Latin square with 4 treatments per block and 4 replications (1). The data were subjected to the analysis of variance and Duncan's multiple range test. Correlation coefficients were computed between Gardner color values and color-related constituents.

Results and Discussion

The period of storage before evaluation of the beans, although not ideal, was necessary because of the distance between the growing area and the laboratory and because of limitations of personnel. With the exception of an insignificant decrease in ascorbic acid, no deterioration in quality was observed.

Color. The PC, 'Custer', had significantly lower Gardner *Rd* and *b* values and significantly higher Gardner *-a* and *-a/b* values and taste panel scores for color than 'Canyon' ($P < 1\%$) (Table 1). Results of the objective and the subjective assessments were in harmony and indicate that the color of 'Custer' both as perceived by the eye and as sensed by the photocells appeared darker, greener, and less yellow than that of 'Canyon'. The values for $\frac{-a/b}{Rd}$ followed the same trend. These findings support

those of Maryland and Dean (14) who reported that 'Custer' was superior in visual color intensity to the normal-green cultivars. No significant differences in color were found between experimental lines XIda 71-2081 and XIda 267-4. The color values for XIda 71-2081 and XIda 267-4 were intermediate between those for 'Custer' and those for 'Canyon'.

The content of total chlorophyll, chlorophyll a, and chlorophyll b was significantly higher and the ratio of chlorophyll a/b significantly lower in the 3 PC beans than in 'Canyon' (Table 1). Similar findings were reported by Mayland and Dean (14). No significant differences among cultivars were found in percent retention of chlorophyll or in content of pheophytin and carotene.

Taste panel color scores and Gardner values for *-a*, *-a/b*, and $\frac{-a/b}{Rd}$ were positively correlated with total chlorophyll,

chlorophyll a, and chlorophyll b (Table 2). They were negatively correlated with Gardner *Rd* and *b* values. This agrees with the work of Eheart and Gott (4) and of Hoffman and Kanapaux (9) who reported highly significant positive correlations between visual color ratings and chlorophyll content of snap beans. The results do not agree with the findings of Mayland and Dean (14).

Chlorophyll *a/b* was positively correlated with Gardner *b* values and negatively with taste panel color scores. Percent chlorophyll retention was positively correlated with Gardner *-a*, *-a/b*, and $\frac{-a/b}{Rd}$ values. These results agree with those of Gold and

Weckel (6) who found a highly significant negative correlation between Hunter values for *-a/b* and the degree of conversion of chlorophyll to pheophytin in heat-processed peas.

No color values were correlated with pheophytin or carotene content.

Since the methods for measuring the color attributes and the chlorophylls were sensitive and reproducible, we have concluded that the correlations are real, at least in the cooked, fresh beans.

Quality attributes. No significant differences due to cultivar

Table 3. Means, standard deviations, and significance of varietal differences in measurements of quality attributes of snap beans.

| Line or cultivar | Taste panel firmness score ^z | Maximum force kg | Work to shear cm-kg | Seed % | Sloughing ml | Fiber % ^y | Taste panel fibrousness score ^x | Taste panel flavor score ^w | Ascorbic acid mg/100g ^v | pH | | Moisture % |
|------------------|---|------------------|---------------------|--------|--------------|----------------------|--|---------------------------------------|------------------------------------|---------------|-----------------|------------|
| | | | | | | | | | | Cooking water | Acetone extract | |
| Custer | 4.9 | 49.8 | 119.9b ^u | 7.08B | 3.2a | 0.53AB | 1.5B | 3.7a | 5.7 | 6.48a | 7.02 | 91.09 |
| XIda 267-4 | 5.0 | 51.2 | 119.1b | 7.83AB | 2.5ab | 0.39B | 1.6B | 4.0a | 7.4 | 6.39ab | 6.91 | 91.98 |
| XIda 71-2081 | 4.8 | 52.6 | 145.8a | 8.82A | 1.8b | 0.89A | 2.4A | 3.4b | 7.5 | 6.34bc | 6.62 | 91.28 |
| Canyon | 5.0 | 49.7 | 120.1b | 5.04C | 2.5ab | 0.26B | 2.0AB | 3.5a | 8.5 | 6.32c | 6.70 | 90.53 |
| S.D. | 0.2 | 3.4 | 15.9 | 1.53 | 1.0 | 0.28 | 0.4 | 0.3 | 0.9 | 0.19 | 0.23 | 0.91 |

^zRange: 9, very tough to 1, mushy. The optimum in texture—tender, yet firm—was assigned a value of 5.

^yDry wt basis.

^xRange: 5, very fibrous, to 1, not fibrous.

^wRange: 5, full natural flavor, to 1, weak or lacking in flavor.

^vMean of 3 replications.

^uMean separation within columns by Duncan's multiple range test at the 1% level with capitals; at the 5% level, lower case; non-significant, no letters.

were observed in taste panel scores for firmness, in max force values, content of ascorbic acid, moisture, or in pH of the acetone extract (Table 3). The fact that the mean scores for firmness were all in the 4.8 to 5.0 range indicates that all cultivars were cooked to the "tender but firm" stage of doneness.

Work-to-shear values were significantly higher for XIda 71-2081 than for the other beans. This bean also had the highest percent seed, the highest percent fiber, and the highest panel scores for fibrousness. The content of seed and fiber may have contributed, at least in part, to the high work-to-shear values. Whether the higher percent seed and percent fiber are attributable to genetic controls or to a slightly greater maturity is unknown. It is possible that under the high-temp, low humidity growing conditions at Twin Falls, XIda 71-2081, a slender-podded cultivar, reached its prime pod maturity at sieve size 4 rather than sieve size 5. No significant differences among the other 3 beans were found in work-to-shear values, panel scores for fibrousness, or amount of sloughing. Although 'Custer' sloughed the most and XIda 71-2081 the least, little or no sloughing was observed in any cultivar. 'Canyon' was lowest in percent fiber and percent seed with 'Custer' and XIda 267-4 intermediate.

All beans were scored as having a slightly to moderately full, natural flavor (Table 3). However, the mean flavor score was significantly lower for XIda 71-2081 than for the other beans.

The pH of the cooking water was highest for 'Custer' and lowest for 'Canyon' with the 2 other beans intermediate.

The vitamin A values calculated from the carotene assays on the fresh-cooked snap beans compared favorably with the values in Agriculture Handbook No. 8 (21) but the ascorbic acid values were slightly lower (Tables 1 and 3). The latter may either have occurred during the period elapsing between harvest and cooking or may have resulted from leaching during the cooling process. In overall acceptability, the PC lines were equal or superior to the normal-green cultivar, with 'Custer' showing the most promise. Studies are currently underway to assess the freezing and canning quality of the cultivars and to determine interrelationships between composition and quality attributes.

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