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Color Evaluations of Delicious Strains

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Abstract

Fruit samples from commercial apple orchards were collected at 145 to 150 days after full bloom in 1985 through 1987. Color measurements were performed on each of 10 fruit at 8 points on the side circumference of each apple using a HunterLab D25 Optical Sensor. Results were recorded as lightness (L), and hue angle (∅). Strains were compared to three standards: 'Redchief,' 'Sturdeespur' and 'Starkrimson.' Significant correlations were found between ∅ and L in all orchards as well as between L values and consumer determinations of overall acceptability and perceived flavor. At all sites, 'Starkrimson' and 'Redspur' consistently had higher L values than any of the other strains indicating lighter colored fruit at harvest. Other strains that appeared to be lighter colored during the harvest period chosen include 'Wellspur,' and 'Redprince.' Within any one year there were significant differences between strains within an orchard. There was more variability within strains than among strains within orchards and years.

Introduction

With over 100 different strains, the 'Delicious' apple cultivar provides a wide selection of genotypes to commercial growers (8). In selecting new strains of 'Delicious,' important traits have been intensity or earliness to color and growth habit. Studies have characterized strains based on firmness, acidity or sugar content (7, 12, 17), primarily in an attempt to determine maturity differences. Color has long been a major determinant in the introduction of new strains by commercial nurseries. Clydesdale (1) proposed that color is perhaps the most important sensory or acceptability attribute of a food material; if consumers perceive poor color they will not purchase the product. Smith and Frye (15) showed that color influenced apple purchases by consumers at retail outlets. With instrumentation, color can be quantified (10, 11); however, colorimeter values may not always coincide with consumer preference (4). The purpose of this study was to quantitatively measure color differences between several strains of 'Delicious' over a period of years and to determine the uniformity of the color.

Fruit of selected strains were harvested at 145 to 150 days after full bloom in each year. The five sites from which the strains were chosen generally represent distinctive fruit growing regions. Site 1 was a commercial orchard in the west central portion of Pa. Site 2 was in central Pa at the Penn State Rock Springs Research Farm. Site 3 was at the Penn State Fruit Research Lab in the largest apple producing county in the state. Site 4 was a commercial orchard in the eastern portion of the state and represents warmer growing conditions. Site 5 was the West Virginia Experiment Farm in Kearneysville, WV. The wide geographical area was chosen to determine if there were strains that might color better in different areas.

The strains chosen were those growing in commercial orchards or the newer strains that have generated considerable interest in the commercial fruit industry. Initially, attempts were also made to collect at least one of the following strains 'Redchief (Campbell),' 'Starkrimson' or 'Sturdeespur' from each site to represent a common stan-

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dard. Those three strains were chosen because of their general popularity among commercial orchardists in the region.

Fruit were collected from the periphery of 3 to 4 trees of each strain in all four quadrants of the tree. Fruit fully exposed to sunlight was chosen to eliminate any effects of pruning, shading or rootstock. PA fruit samples were from mature trees while those from WV were from trees planted in 1981-1983 as described by Warrington et al. (16). None of the fruit collected were from trees that had been treated with daminozide in any of the test years.

Color was measured with a Hunter-Lab D25 Optical Sensor that had been standardized to a red plate (L = 28.3, a = 50.0, b = 16.8). Each of the ten apples was wiped to remove any spray residue, but not polished. The apple was presented to the portal at 8 separate points along the midsection of the fruit; the eight readings were then averaged for a single apple. Results were recorded in L, a, and b values. The L, a, b system places the average of the 8 readings of each apple in a 3-dimensional color space based on the color-opponent theory. The "L" value represents the lightness of the sample with a "0" indicating darkness and 100 lightness. A positive "a" value corresponds to the degree of redness while a negative value corresponds to greeness. A positive "b" value represents the degree of yellowness with a negative value representing blueness. From these values the hue angle of a specimen can be mathematically derived from the following formula (1)

$$\text{Hue angle } (\varnothing) = (\tan^{-1} b/a) * 57.3$$

Hue angle (∅) is the angle formed by plotting the a and b values and drawing a line through the origin. In simpler terms, hue describes what the average person thinks of when speaking of color (1). Hue is known to be psychologically correlated with visual acceptance of many foods (1, 9). The lower the value the more red the sample.

Bartlett's Test for Homogeneity indicated that the variances were nonhomogeneous, therefore the nonhomogeneous data could not be used in the analysis of variance. Data that did have homogeneous variances were analyzed by analysis of variance after the values were transformed to logarithms. Strains with variances that remained excessively high after transformation ($p > 0.05$) were considered too variable and were dropped from the data set. Analysis of variances and mean separations were made on transformed data in each year for each orchard. Mean separation for the data from Site 5 was performed using Tukey's Multiple Range Test because of the large number of strains and the need for control over making a Type I error. Fisher's Protected LSD was used on the other sites because of the fewer number of strains involved.

Additional samples of selected strains were collected for taste panel evaluations in 1986. Six strains of 'Delicious' apples were evaluated for flavor, crispness, and overall acceptability by 271 participants using a nine-point scale ranging from 1 for "dislike extremely" to 9 for "like extremely." The apples were unpeeled, cored and cut into eight sections. Each person sampled one section from each of three of the six strains using a balanced incomplete block design (3). The initial evaluation of the six strains was conducted approximately one week after harvest followed by a subsequent evaluation 67 days later. The apples were stored in refrigerated storage maintained at approximately 0 C. Pearson correlation coefficients were determined between overall acceptability, flavor and crispness and L value and hue angle.

An analysis of the differences among the chosen standard strains and other strains across all years indicated that most strains were significantly different among years. Years were therefore

Table 1. Color measurement values of several strains of Delicious collected 145-150 days after full bloom from several locations in Pennsylvania in 1985-87.

		1985		1986		1987	
Strain	Site	L value[z]	Hue Angle (Ø)[z]	L value[z]	Hue Angle (Ø)[z]	L value[z]	Hue Angle (Ø)[z]
Classic	1	23.0 b[y]	42.9 a	—	—	17.9 cd	20.1 b
Earlibright		—	—	—	—	19.4 bc	25.7 a
Redchief		21.3 b	39.6 a	—	—	16.0 d	23.0 b
Starking		—	—	24.8 a	26.8 a	24.0 a	X[x]
Starkrimson		—	—	21.1 b	23.4 a	21.6 ab	X
Sturdeespur		26.6 a	X	23.7 a	25.7 a	20.1 bc	X
Topred		—	—	20.5 b	20.3 a	—	—
Early Red One	2			18.5 c	15.6 b	—	—
Nured Royal				20.5 b	18.2 b	—	—
Redspur				22.9 a	23.4 a	19.2 b	22.8 a
Redchief (Campbell)				—	—	17.8 b	X
Redchief (Mercier)				—	—	14.9 c	24.8 a
Silverspur				23.2 a	22.2 a	—	—
Spured Royal				20.0 b	X	—	—
Starkrimson				—	—	17.4 b	15.2 b
Starkspur Compact				20.1 b	17.6 b	18.9 b	16.5 b
Topred				—	—	23.7 a	24.8 a
Ultrared				X	X	—	—
Imperial	3	25.5 b	X	23.0 ab	21.2 a	—	—
Redchief		19.9 c	18.3 c	21.7 b	21.2 a	23.4 a	25.6 b
Starkrimson		25.0 b	32.9 a	23.4 ab	24.0 a	24.7 a	X
Strudeespur		25.0 b	26.4 b	22.4 ab	23.5 a	—	—
Vance		27.4 a	X	24.3 a	23.2 a	27.2 a	33.0 a
Brite 'n Early	4	—	—	19.6 b	19.4 b	—	—
Imperial		20.8 b	X	24.3 a	23.2 a	—	—
Redprince		X	X	—	—	32.1 a	X
Starkrimson		X	X	24.1 a	21.6 ab	23.2 c	X
Starkspur Supreme		20.3 b	X	23.4 a	23.5 a	23.0 c	29.1 a
Starkspur Ultrared		19.8 b	22.7 a	20.1 b	20.2 b	19.2 d	20.7 c
Redchief		19.8 b	X	21.0 b	19.7 b	20.1 d	25.4 b
Redspur		24.2 a	27.2 b	23.8 a	21.9 ab	26.4 b	28.7 a

[z]The lower the value the darker the color (L), the redder the fruit (Ø).
[y]Mean separation within orchards and years by Tukey's Multiple Range test ($p < 0.05$) on transformed data. Actual means represented in table.
[x]Data collected but variances were nonhomogeneous, therefore values not shown.

considered separately. There were, however, more significant differences among orchards and hence each orchard must be considered separately. Therefore, the data will be reviewed on a per year basis within orchards.

Finally, another important consideration from a commercial packout point

of view is consistency of color. To assess consistency of color the variances of L values and ∅ were also examined. Strains consistently having a high variance in these parameters may pose problems due to a nonuniform tray pack.

Results

Site 1: In 1985 'Sturdeespur' performed the poorest by having the lightest fruit and a highly variable ∅ (Table 1). In 1986 'Topred' and 'Starkrimson' fruit were darker than 'Sturdeespur' or 'Starking' but there were no significant differences in the hue angle. 'Redchief' was the darkest coloring fruit in 1987 with 'Classic' being similar. The ∅ of 'Starkrimson,' 'Sturdeespur' and 'Starking' was so variable that these data had to be dropped.

Site 2: In 1986 'Early Red One' was the darkest among all the strains. 'Silverspur' and 'Redspur' had the highest ∅ and L value. Individual fruit of 'Starkspur Ultrared' varied to the extent that neither L value nor the ∅ data could be used. In 1987 'Redchief (Mercier)' had the darkest fruit of all strains; it was significantly better than the standards of 'Redchief' and 'Starkrimson.'

Site 3: 'Redchief' was the darkest coloring strain in both 1985 and 1986; and had the lowest ∅ of all strains in 1985. There were no differences in ∅ in 1986 or L values in 1987 among the strains.

Site 4: In 1985 only 'Redspur' had a significantly higher L value, indicating lighter colored fruit. There was a high amount of variance in ∅ of the fruit from this site in 1985 as evidenced by the necessity to exclude data from five of the seven cultivars. 'Redchief,' 'Starkspur Ultrared' and 'Brite 'n Early' had the lowest L values and ∅ in 1986. In 1987 'Redchief' and 'Starkspur Ultrared' were the darkest coloring strains; with 'Starkspur Ultrared' having a significantly lower hue angle.

Site 5: In 1985 ∅ of 'Sturdeespur' was significantly lower than 'Apex,' 'Hardibrite,' 'Redspur,' 'Ruby Red,' and 'Waynespur' (Table 2). 'Oregon Spur II' and 'Silverspur,' however, had significantly darker fruit than 'Sturdeespur.' In 1986 'Sturdeespur' and 'Redchief' had similar L values and ∅ but were significantly darker than 'Starkrimson.' 'Cascade Spur,' 'Oregon Spur,' and 'Ryanred' had significantly higher ∅. 'Scarletspur' was the darkest coloring strain, significantly darker than 'Redchief,' but not 'Sturdeespur.' In 1987, 'Redchief' was significantly darker than 'Alred,' 'Apex,' 'Starkrimson,' 'Real McCoy,' 'Redprince,' and 'Wellspur.' 'Starkspur Ultrastripe' was the darkest strain being significantly darker than 'Sturdeespur' and 'Starkrimson' but not 'Redchief.'

'Starkrimson' tended to be the most variable. Other strains that showed color variability either two years or at more than one site included, 'Hardibrite,' 'Imperial,' 'Real McCoy,' 'Redchief (Campbell),' 'Redprince' and 'Sturdeespur.' The variability in color characteristics could be considered detrimental to those commercial growers that are tray packing large quantities. L values varied the least across all sites, with only 9 strains having to be dropped over the three years (Tables 1 & 2). In contrast 28 strains had ∅ values whose variances were nonhomogenous.

Correlation coefficients between L values and overall acceptability, $R = 0.87$ ($p > 0.03$) and perceived flavor $R = 0.87$ ($p > 0.03$) were found at harvest (Table 3). There were no significant relationships between ∅ and taste variables; nor were there significant relationships between the taste variables and any color measurements at 67 days postharvest.

Discussion

Contrary to previous reports (4, 13) we could not find consistent significant differences in either L or ∅ between our chosen standards and the other strains over the three year course of

Table 2. Color measurement values of several strains of Delicious collected 145-150 days after full bloom from The West Virginia Experiment Station, Kearneysville, WV in 1985-87.

	1985		1986		1987	
Strain	L value[z]	Hue Angle (Ø)[z]	L value[z]	Hue Angle (Ø)[z]	L value[z]	Hue Angle (Ø)[z]
Ace	22.5 bcd[y]	26.3 abcde	21.7 efg	19.4 cd	21.6 ef	21.7 fg
Alred	—	—			29.3 ab	32.5 abcd
Aomori	—	—	26.0 abc	X[x]	25.3 bcde	24.3 cdefg
Apex	24.0 abc	27.3 abc	22.8 cdefg	20.2 cd	29.0 ab	34.6 ab
Bright 'n Early	—	—	22.8 cdefg	23.7 abcd	22.3 ef	X
Cascade Spur	23.6 abcd	23.5 cdefg	X	26.6 ab	25.7 abcde	22.3 efg
Classic	—	—	25.0 abcde	23.2 abcd	25.2 bcde	25.1 bcdefg
Dixiered	—	—	20.3 fg	19.4 cd	—	—
Hardi-Brite	X	29.3 a	25.4 abcd	X	28.2 ab	27.6 abcdefg
Imperial	23.2 bcd	25.6 abcdef	24.0 bcde	21.7 abcd	22.1 ef	X
Improved Ryanred	—	—	25.5 abcd	24.6 abcd	22.5 def	20.6 g
Nured Royal	—	—	24.8 abcde	20.0 cd	—	—
Oregon Spur	X	X	27.2 ab	29.5 a	—	—
Oregon Spur II	21.5 d	22.1 gf	24.4 abcde	24.2 abcd	—	—
Real McCoy	—	—	25.5 abcd	X	27.5 abcd	X
Redchief	—	—	23.1 bcdef	20.3 bcd	22.1 ef	26.5 abcdefg
Redprince	—	—	—	—	31.5 a	31.3 abcde
Redspur	25.8 a	27.6 ab	28.6 a	X	25.2 bcde	33.1 abc
Rose Red	—	—	24.7 abcde	20.9 bcd	—	—
Ruby Red	22.7 bcd	27.1 abc	24.5 abcde	24.8 abcd	24.0 bcde	28.8 abcdef
Ruby Stripe	—	—	24.4 abcde	23.4 abcd	23.0 cdef	23.2 defg
Ryanred	—	—	24.6 abcde	25.1 abc	—	—
Ryanspur	—	—	—	—	27.1 abcde	34.2 abc
Scarletspur	—	—	19.7 g	19.0 cd	23.0 def	X
Sharp Red	—	—	24.1 bcde	23.5 abcd	24.4 bcde	24.6 bcdefg
Silverspur	21.9 cd	21.7 f	23.0 cdefg	20.3 bcd	23.1 def	23.5 cdefg
Starkrimson	—	—	28.5 a	X	28.9 ab	36.8 a
Starkspur Supreme	—	—	24.2 bcde	25.3 abcd	—	—
Starkspur Ultrared	—	—	22.2 defg	19.4 cd	24.8 bcde	22.5 fg
Sturdeespur	24.1 ab	23.0 efg	22.7 cdefg	18.7 d	25.9 abcde	23.3 defg
Topred	—	—	24.7 abcde	24.3 abcd	26.2 abcde	27.4 abcdefg
Topspur	23.7 abc	23.3 defg	23.6 bcdef	21.3 bcd	26.4 abcde	29.5 abcdef
Ultrastripe	—	—	21.4 efg	19.5 cd	19.4 f	X
Waynespur	X	26.8 abcd	24.1 bcde	21.0 bcd	22.1 ef	23.9 cdefg
Wellspur	24.3 ab	24.7 bcdefg	25.4 abcd	22.9 abcd	28.7 abc	30.6 abcdef

[z]The lower the value the darker the color (L), the redder the fruit (Ø).
[y]Mean separation within years by Fisher's Protected LSD ($p < 0.05$) on transformed data. Actual means represented in table.
[x]Data collected but variances were nonhomogeneous, therefore values not shown.

this study; although in any one year at any one site we were able to show differences. It appears that there is considerably more variability within strains of apples than among strains within orchards and years. In both the previous two studies, data was based on a single year. The relative order of

'Starkrimson,' 'Redchief' and 'Sturdeespur' varied considerably from orchard to orchard.

There appeared to be no consistent significant trends from the West Virginia data for either Ø or L values. However, in a numerical listing of those strains that had lower L values and Ø than 'Redchief' in 1986 and 1987, 'Ace' and 'Starkspur Ultrastripe' appear in both parameters in the two years (not shown). Using 'Sturdeespur' and comparing L values; 'Ace' appears in all three years. 'Brite 'n Early,' 'Starkspur Ultrared,' 'Starkspur Ultrastripe' and 'Scarletspur' ranked lower than 'Sturdeespur' in 1986 and 1987. There were no common strains that had lower Ø in two or three years. Baugher et al. (2) reported that a consumer panel instructed to rate overall color on a scale of 1 to 10 found that 'Starkspur Ultrastripe' and 'Scarletspur' consistently rated as high coloring strains whereas 'Hardi-Brite Spur' and 'Real McCoy' consistently rated lower. The objective results in this study tended to support that conclusion, although the Ø of 'Starkspur Ultrastripe' and 'Scarletspur' in 1987 were too variable to utilize the data as well as the Ø of 'Real McCoy' in 1986 and 1987 (Table 2).

Previous work (4) in north Georgia had shown that 'DixieRed' and 'Early Red One' were better coloring than 'Redchief' in a single year's study. The strain identified as 'Grower Sport #2' in the 1984 study was later commercially released as 'Redchief' (Mercier) and when compared to the original 'Redchief' (Campbell) at Site 2 in 1987 was significantly darker.

Polesello and Gorini (13) also in a single season evaluation of 26 strains found that 'Ryan Red' was the darkest coloring strain. In this study at WVU in 1986, 'Ryan Red' was not significantly lighter than 'Redchief' but there were several strains that had lower L values than 'Ryan Red.' They further classified the strains into 6 groups based on hue angle with group 1 being mainly yellowish (Ø = 70-90) to group 3.3 (20-25) being intensely colored. The better coloring strains in this study fell into or below their classification for group 3.3.

'Starkrimson' and 'Redspur' at all sites consistently had higher L values at harvest. Other strains that appeared to be lighter colored during the harvest period chosen include 'Wellspur,' and 'Redprince.' Since all strains were harvested at a predetermined time, color differences may lessen had the fruit been allowed to remain on the tree longer.

Since many of the strains are known to have distinctive color pattern development (2, 8) the necessity to eliminate certain sets of data due to nonhomogenous variances may have been related to an uneven development of the pattern. Variability of the color components measured based on color pattern at Site 5 showed that 6 of the strains where data was dropped, typically develop a blush pattern of coloration, 4 of the strains have a striped pattern and 2 develop color beginning as a stripe then filling in with a blush. Most of the variability appeared to occur in the data pertaining to the hue angle.

It has been reported that color is a strong determinant in consumer acceptability of a food product (11, 15). The significant correlation coefficients between overall acceptability and flavor and the L values (Table 3) suggests the component that appeared most important was the L value of the fruit. Furthermore, since there was a greater occurrence of nonhomogenous variances of Ø values may also support the importance of fruit darkness as opposed to actual color. Smith and Frye (15) and Baugher et al. (2) did not separate the components of color in their study; therefore, it is possible that the consumers in these two studies may have been evaluating acceptability based on darkness of the apples.

One factor that could not be accurately measured in this study is the

Table 3. Correlation coefficients of L values and the hue angle (∅) between consumer panel evaluations of overall acceptability, flavor and crispness at harvest and 67 days postharvest.

	R values					
	At Harvest			67 days postharvest		
Color Parameter	Overall Acceptability	Flavor	Crispness	Overall Acceptability	Flavor	Crispness
L value	0.87	0.87	0.46	0.62	0.39	0.64
significance	0.03	0.03	0.36	0.13	0.39	0.11
Hue angle (∅)	0.65	0.63	0.50	0.19	0.18	0.12
significance	0.16	0.18	0.31	0.68	0.70	0.79

absolute effect of temperature and light upon the color components. Although Site 3 was regarded to be a warmer region the individual temperatures and light levels during those years were not recorded in this study. Robinson et al. (14) indicated on 'Strudeespur' in Washington State fruit color was not influenced by a range of sunlight from 5% to 95% full sun in subjective evaluations. Since fruit was collected from the outside periphery and fully exposed it is assumed that the color was a function of the light levels within the orchard and it was not altered by shading. A further avenue of study would be to look closer at the effects of color within the tree canopy and measure objectively the color and its rate of development on multiple strains.

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