17. Shaulis, N. J., H. Amberg, and D. Crowe. 1966. Response of Concord grape light, exposure and Geneva double curtain training. Proc. Am. Soc. Hort. Sci. 89:268-80.
18. Sims. V. A. and J. R. Morris. 1984. Effects of pH, sulfur dioxide, storage time and temperature on color and stability of red muscadine grape wine. Am. J. Enol. and Vitic. 35(1):35-39.
19. Smith, C. B., H. K. Fleming and J. H. Poorbaugh. 1957. The nutritional status of Concord grape vines in Erie County, Pennsylvania as indicated by petiole and soil analyses. Proc. Am. Soc. Hort. Sci. 70:189-196.
20. Snedecor, G. W. 1946. Statistical methods. 4th Ed. Iowa State Univ. Press. Ames, IA. pp. 123-93, 413-446.
21. Waller, R. A., and D. B. Duncan. 1969. A bayes rule for the symmetric multiple comparison problem. Am. J. Stat. Assoc. 64: 1484-503.

Fruit Varieties Journal 45(1):33-36 1991

Relationship Between Visual Rating and Chromaticity Values in 'Delicious' Apple Strains[1]

SUMAN SINGHA,[2] EDWIN C. TOWNSEND, AND TARA A. BAUGHER

Abstract

Fruit of 37 'Delicious' apple (*Malus domestica* Borkh.) strains were harvested 149 days after full bloom in 1988, and visually evaluated by panelists on a 1 to 10 scale, where 10 = excellent color. Fruit color was measured at the mid point between the stem and calyx end on the blushed surface of each fruit with a Minolta Chroma Meter CR-200b portable tristimulus colorimeter. A simple linear regression of color panel rating on L* value provided a $R^2 = 0.55$, indicating that this parameter influences visual color evaluation. However, the a*/b* ratio was the best single predictor of color rating ($R^2 = 0.63$). Although several models were tested, and many were statistically significant, none appeared to be better than the a*/b* ratio from a practical standpoint. Assessing fruit color with a colorimeter eliminates the problems of subjectivity associated with visual ratings and permits color to be reported in internationally accepted units.

Introduction

Fruit color is an important characteristic of 'Delicious' strains and influences both consumer acceptance (3) and sales (10). Consequently, a major criterion in the selection of new strains is their higher red coloration (5). Visual assessment of fruit red color is a primary basis for the U.S. grade standards (11), and low coloration is an important cause for reduction in grade (1). Cultural practices that improve red color include growth regulator sprays (8), orchard nutrition (12) and summer pruning (9). Evaluation of fruit color following field investigations generally utilize sensory (numerical rating) methods (2, 8). Whereas this approach is adequate from the standpoint of U.S. grade standards which have wide variations, it can be problematic from a research standpoint because treatment differences may be less dramatic and because the subjective nature of sensory ratings makes it difficult to quantify and compare results from different studies. The development of portable, easy-to-operate, tristimulus colorimeters permit quantification of fruit coloration in internationally acceptable units, thereby allowing more reliable and consistent comparisons of fruit color.

The objective of the present study was to determine the relationship between sensory color evaluation and Commission Internationale d'Eclairage (CIE) L* a* b* Color Space coordinates (7) measured with a Minolta Chroma Meter CR-200b portable tri-

[1]Approved for publication by the Director, West Virginia Agric. and For. Expt. Stn. as Scientific Article No. 2225.
[2]Present address: Department of Plant Science, The University of Connecticut, Storrs, CT 06269-4067.

stimulus colorimeter. An additional objective was to compare the fruit color in 37 'Delicious' strains.

Materials and Methods

Fruit of the 37 strains used for this study were obtained from the 'Delicious' strain evaluation block at the West Virginia University Experiment Farm at Kearneysville, WV. Fruit were harvested from the outer periphery of the trees 149 days after full bloom in 1988 and gently wiped with a soft cloth to remove any spray residues or dust. Four representative fruit of each strain were presented to the panelists with the sun-exposed (blushed) surface facing the evaluators. The 13 member panel, most of whom had experience in evaluating fruit color, were instructed to rate the fruit of each strain on a 1 to 10 scale (where 10 = excellent color). Fruit color was measured by placing the 8-mm-diameter measuring area of the Minolta CR-200b at the mid point between the stem and calyx end on the blushed surface of each fruit presented to the panelists. The instrument has a self-contained light source that provides diffuse, uniform lighting over the sample surface. It measures the color of the reflected light and provides a digital output in either the L* a* b* or CIE Y, x, y coordinates (7). the meter was calibrated at illuminant condition C (6774K) with a white standard (Minolta calibration plate CR-A43) and fruit chromaticity measured in L* a* b* coordinates. In this system L* represents the value (lightness) of colors, it is small for dark colors and large for light colors; a* is negative for green and positive for red, whereas b* is negative for blue and positive for yellow.

Results and Discussion

Although evaluating differences between strains was not the primary objective of this study, strains with darker red coloration (lower L* value) included 'Redchief,' 'DixieRed,' 'Scarlet

Table 1. Chromaticity values and panel rating of 'Delicious' strains at harvest.

Strain	L*	a*	b*	Panel Rating[z]
Ace	32.7	22.2	7.5	7.9
Alred	43.3	26.0	14.3	3.4
Aomori	38.4	27.0	13.1	4.7
Apex	35.7	26.1	9.5	7.7
ACN 501	34.1	25.1	9.2	7.0
Bright'n Early	37.8	25.8	11.9	6.9
Cascade Spur	33.1	25.9	8.9	8.7
Classic	40.7	27.9	13.6	5.6
DixieRed	32.2	21.1	6.6	6.4
Hardi-Brite Spur	37.2	24.7	10.4	5.5
Imperial	36.4	27.5	11.5	6.5
Improved Ryanred	36.6	24.8	10.6	5.3
Nured Royal	37.6	26.8	11.1	7.1
Oregon Spur	38.0	22.5	9.1	6.6
Oregon Spur II	34.3	22.5	7.9	9.1
Real McCoy	38.9	26.4	12.9	5.2
Red Prince	39.9	27.2	13.0	5.4
Redchief (Campbell)	31.9	24.1	9.1	7.5
Redspur	37.7	25.3	10.9	5.9
Rose Red	38.2	28.5	12.7	6.0
Ruby Red	33.8	26.3	9.5	6.6
Ruby Stripe	36.5	26.7	9.7	7.3
Ryanred Spur	32.9	20.2	8.3	6.3
Scarlet Spur	32.5	21.3	7.3	8.8
Sharp Red	38.9	24.8	11.5	5.6
Silver Spur	35.1	22.7	9.3	6.0
Spur Red	36.4	23.2	9.6	6.1
Starkrimson	37.3	26.9	10.9	5.6
Sturdeespur	36.7	25.7	10.2	6.6
Supreme	37.9	24.9	11.2	4.0
Topred	40.2	27.4	15.7	5.0
Topspur	36.7	25.9	11.1	4.6
Triple Red	37.0	24.6	11.2	5.7
UltraRed	34.3	25.4	10.0	7.7
UltraStripe	32.6	22.3	7.5	8.5
Wayne Spur	35.9	27.0	11.6	6.2
Wellspur	37.2	25.0	11.9	5.4
LSD (0.05)	4.4	3.7	3.4	0.2

[z]Panel rating on a 1 to 10 scale (where 10 = excellent color).

Spur,' 'UltraStripe,' 'Ace,' and 'Ryanred Spur' (Table 1). Similar to the findings of Crassweller et al. (4). 'Classic,' 'Rose Red,' 'Sharp Red,' and 'Red Spur' had lighter coloration.

As expected there were significant differences among strains in the a* value (a measure of redness) (Table 1). However, even wider variations existed among the strains in the b* value (a measure of yellowness) (Table 1), and this strongly influenced both the a*/b* ratio and the color panel ratings (Fig. 1). For example, 'Alred' and 'Apex' had similar a* values, but 'Alred' had a significantly higher b* value, resulting in a low a*/b* ratio and a low panel rating for this strain (Fig. 1). The a* value by itself related very poorly to the color panel ratings (Table 2). A simple linear regression of color panel rating on L* value provided a $R^2 = 0.55$ (Table 2), indicating that this parameter influences visual color evaluation. However, the a*/b* ratio was the best single predictor of color rating (Table 2, Fig. 1) and is superior to chroma ($\sqrt{a^{*2} + b^{*2}}$) but similar to hue angle ($\tan^{-1} b^*/a^*$). Although the visual rating of foods often correlated better to hue angle (6), over the range of a*/b* ratios in these 'Delicious' strains, there is essentially a linear relationship between hue angle and a*/b* ratio and consequently either may be used.

It should be pointed out that certain strains tended to be rated much lower by the panelists than other strains with similar a*/b* ratios (Fig. 1). 'Alred' with a a*/b* ratio similar to 'Topred' was the lowest rated strain. This may be attributed to the heavy stripe in this strain, which appears to be a detractant and thus lowers its rating. The lack of uniformity in fruit color in 'Supreme' and 'Topspur' may have been the cause of their lower panel

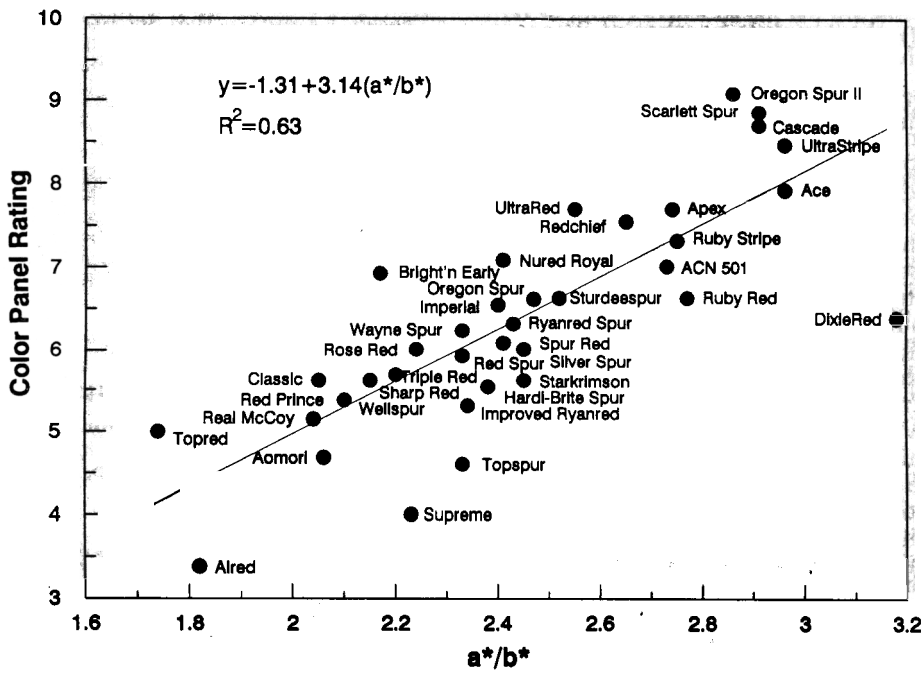

Figure 1. Relationship between color panel rating and a*/b* ratio in 'Delicious' apple strains.

Table 2. R^2 for selected regression models relating chromaticity values to color panel rating.

Variables in equation	R^2
chroma[z]	
b*	0.52
L*	0.55
hue angle[y]	0.62
a*/b*	0.63
L*, a*, b*	0.63
L*,a*/b*	0.64
L*, L* (a*/b*), b*[2]	0.66
a*/b*, a*(a*/b*), (a*/b*)[2], chroma, chroma (a*/b*)	0.73

[z]chroma = $\sqrt{a^{*2} + b^{*2}}$.
[y]hue angle = $\tan^{-1}$ b*/a*.

ratings. 'DixieRed,' with the highest a*/b* ratio, was probably downgraded by the panelists because of its excessively dark coloration.

The highest R^2 value (0.73) was obtained when 5 terms were included in the multiple regression model (Table 2). Although several models were tested, none of them appear to be any better from a practical standpoint than the simple linear regression of color panel rating on the a*/b* ratio. In this study we intentionally used a large number of strains with a wide variation in coloration so that any relationship between subjective panel ratings and objective instrumental values would have a wide range of applicability. Even with outliers like 'Alred,' 'Supreme' and 'DixieRed,' which tend to reduce the R^2 value, the instrumentally measured a*/b* ratio effectively relates to the color panel ratings. Furthermore, it provides a simple method for reporting fruit color in internationally accepted terms which would eliminate the qualitative problems associated with visual ratings.

Literature Cited

1. Baugher, T. A., H. W. Hogmire, and G. W. Lightner. 1990. Determining apple packout losses and impact on profitability. Applied Agric. Res. 5: (in press).
2. Blizzard, S. H., S. Singha, T. A. Baugher and B. D. Cayton. 1988. Yield and fruit quality of apple trees under three high density management systems. Fruit Var. J. 42:67-72.
3. Crassweller, R. M. and R. A. Hollender. 1989. Consumer evaluation of 'Delicious' apple strains. Fruit Var. J. 43:139-142.
4. Crassweller, R. M., J. Walker, and R. L. Shewfelt. 1984. Color evaluation of seventeen strains of 'Delicious.' Fruit Var. J. 39:21-24.
5. Fisher, D. V. and D. O. Ketchie. 1981. Survey of literature on red strains of 'Delicious.' Wash. State Univ. College of Agr. Res. Centr. Bul. 0898. 17 pp.
6. Francis, F. J. and F. M. Clydesdale. 1975. Food colorimetery: theory and applications. Avi Publishing, Westport, CT.
7. Hunter, R. S. 1975. The measurement of appearance. Wiley-Interscience, New York.
8. Miller, S. S. 1978. Effect of daminozide and ethephon on maturity and color development of 'Delicious' apples grown in a warm climate. Proc. Plant Growth Reg. Working Group. 5:195-201.
9. Morgan, D. C., C. J. Stanley, R. Volz and I. J. Warrington. 1984. Summer pruning of 'Gala' apple: The relationship between pruning time, radiation penetration, and fruit quality. J. Amer. Soc. Hort. Sci. 109:637-642.
10. Smith, H. M. and R. E. Frye. 1964. How color of Red Delicious apples affects their sales. USDA Marketing Res. Rep. 618. 11 pp.
11. USDA Agricultural Marketing Service. 1972. United States standards for grades of apples. Amended 1 Oct. 1966 and 1 July 1972. Washington, D.C. F.R. Doc. 67-7604.
12. Weeks, W. D., F. W. Southwick, M. Drake and J. E. Steckel. 1958. The effect of varying rates of nitrogen and potassium on the mineral composition of McIntosh foliage and fruit color. Proc. Amer. Soc. Hort. Sci. 71:11-19.