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Ground Color Measurements of Peach

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Abstract. **The relationship of ground color to maturity was examined for 13 cultivars of peach [*Prunus persica* (L.) Batsch]. Samples representing a range in maturity for each cultivar were tested for flesh firmness and surface ground color at harvest. After ripening, the same lots of peaches were measured for ground color, soluble solids, titratable acid, taste, and visual appearance. Color was measured with a colorimeter in Hunter "L", "a", and "b" color coordinates and compared with a series of color references. Peaches selected as being of threshold maturity at harvest, based on taste ratings and firmness, showed average ground color readings of L = 61.2, a = −5.4, and b = 26.8, with results for individual cultivars narrowly distributed in this region of color space. Differences in ground color for varying maturities occurred primarily in the "a" coordinate, which increased as maturity advanced. On average, ground color was a better at-harvest indicator of edible quality after ripening than flesh firmness. Color references used for grading in California did not match actual ground color measurements for peaches grown in South Carolina.**

Flesh firmness and surface color generally are used as indices of maturity for fresh peaches. Rood (7) examined a range of maturity parameters, in relation to panel ratings of general acceptability after ripening, and ranked in order of usefulness as estimators of edible quality: flesh firmness, skin ground color, flesh color, chlorophyll content of the flesh, titratable acidity of the juice, and soluble solids of the juice. Flesh firmness usually is measured with a manual tester by recording the force necessary for a blunt tip to puncture the flesh of a pared cheek. Several types of firmness testers are available, all of which work on the same principal though yield slightly different results (1). A fundamental disadvantage of these firmness measurements is that the test is destructive.

Peach color has been measured using a variety of techniques and related to other maturity parameters. Spectral reflectance curves during maturation showed an increase in reflectance at 675 nm, corresponding to a decrease in chlorophyll absorption, and a decrease in reflectance at 500 nm, indicating an increase in red and yellow pigments (3). Similar measurements demonstrated that the ratio of surface reflectance at 675 nm to 625 nm correlated significantly with flesh firmness measurements and panel rankings of maturity (6). In contrast with spectrophotometer readings at discrete wavelengths, other measurements of peach color have been made using tristimulus colorimeters. These instruments provide readings of color in 3-dimensional color space by computing weighted integrals of spectral refectance over the range of visible wavelengths. Using such a colorimeter, Sims and Comin (8) measured a variety of maturity characteristics as a function of days required to ripen after harvest. Good correlations were reported between firmness and surface color and between firmness and the soluble-solids-to-acid ratio. The authors suggested that colorimeter readings could be used to develop standard grades of ground color for peaches. Several other researchers have reported good correlations between colorimeter readings of flesh color and flesh firmness (2, 9).

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Current USDA grade standards for peaches specify mature but not overripe fruit with varying percentages of surface blush corresponding to the higher grades. Recently, the California Tree Fruit Agreement (CTFA) has implemented a series of minimum ground color requirements for fresh peaches supplemental to the USDA grade standards (1981 California Tree Fruit Agreement, 701 Fulton Ave., Sacramento, CA 98865). Ground colors are specified for each cultivar from a series of 13 color reference shades. No more than 10% of the peach surface may be greener than the designated color references shade, and no more than 10% of the lot may fail this requirement.

Our objectives in this study were to measure peach ground color as a function of maturity and to examine its relationship with other maturity indices, to measure the extent of ground color differences among cultivars, and to assess current ground color reference charts. Colors were measured in coordinates sufficient for latter specification of color reference shades.

Materials and Methods

Fruit handling. Commercially grown peaches were selected in 1982 from orchard blocks throughout the Ridge area of South Carolina. For each sample of a given cultivar, 3 maturity categories of 30 peaches each were selected by visual examination and feel. These categories corresponded to 3 approximate stages of development and were designated preliminarily as immature, threshold mature, and mature. "Immature" peaches are fruit that have nearly ceased physical growth but have not reached physiological maturity and will not ripen properly. "Threshold mature" peaches have just reached physiological maturity and, hence, continue normal ontogenic development after harvest. "Mature" peaches are past the maturity of fruit in the threshold mature category but have not undergone ripening. (ASHS Working Group Report. 1980. Fruit development, maturation, and senescence.)

Immediately after selection, 10 peaches in each category were tested for flesh firmnness. The remaining 60 peaches (20 per category) were stored at 2°C for one or 2 days. Color measurements were made upon receipt of each sample (preripen analysis). The peaches were then kept in a 27° room until judged to be ripe by visual inspection and feel. Ripe categories of each sample were kept in storage at 2° until all 3 categories had ripened. Note that by definition, peaches in the immature categories could not ripen properly. Postripen analysis included measurements of color, soluble solids, total titratable acid, taste

Table 1. Color reference series used for visual matching of ground colors.[z]

Color reference	L	a	b	1982 California designation
1	49.4	−9.5	21.0	A
2	59.2	−10.0	30.2	B
3	61.4	−7.2	28.1	C
4	68.2	−8.2	28.8	D
5	66.7	−6.2	27.8	E
6	67.4	−6.4	29.7	F
7	69.5	−5.6	31.3	G
8	69.7	−3.2	31.4	H
9	76.3	−3.8	31.9	I
10[y]	78.8	−4.3	37.5	J
11[y]	80.4	−5.3	41.6	K
12[y]	80.3	−3.4	40.9	L
13	74.4	+0.4	39.2	M
14	52.0	−10.3	21.6	
15	53.5	−10.2	22.2	
16	54.6	−10.0	22.6	
17	55.6	−9.8	23.1	
18	56.8	−9.7	23.6	
19	56.4	−9.6	23.4	
20	57.1	−9.5	23.6	
21	57.8	−9.2	24.2	
22	59.3	−9.0	24.6	
23	60.3	−8.6	25.2	
24	61.6	−8.3	25.8	
25	63.2	−7.9	26.6	
26	64.6	−7.4	27.3	
27	65.4	−7.0	27.8	
28	66.0	−6.9	28.2	
29	67.2	−6.4	28.8	
30	67.8	−6.1	29.3	
31	68.5	−6.0	29.6	

[z]All readings taken with 9.5-mm viewing aperture for colors in plastic holders, except 2, 8, and 10–12 which were laminated. References 1–13 were used by the California Tree Fruit Agreement during 1982.
[y]Not used in this report.

rating, and visual rating. All color measurements were made on peaches without washing, brushing, or waxing. One to 5 samples of 13 cultivars, ranging from early to late maturing, were analyzed.

After completion of all color and maturity analyses for each sample, the maturity category designations were evaluated based on average taste panel ratings. Often a category thought to be immature was later designated as threshold. Therefore, complete data are reported for the threshold and mature categories.

Color measurement. A circle about 2.5 cm in diameter was marked on 10 of the 20 peaches in each category, corresponding to a visual estimate of the greenest area. Usually this identified area was on the peach shoulder. Color measurements were made with a colorimeter (Model D25A-2, F, STH. Hunter Laboratory Associates, 11495 Sunset Hill Rd., Reston, VA 22090) utilizing 45° diametrically opposed illumination with a 6.4-mm viewing aperture. The small viewing aperture minimized effects of surface curvature and enabled precise isolation of the marked area. Due to the directional illumination of the colorimeter, each peach was rotated 90° on axis and the corresponding 4 readings were averaged. Color measurements were recorded using the Hunter "L", "a", "b" scales (4). The "L" scale ranges from no reflection (L = 0) to perfect diffuse reflection (L = 100), the "a" scale ranges from negative values for green to positive values for red, and the "b" scale ranges from negative values for blue to positive values for yellow. All color measurements are referenced to the CIE (Commission Internationale de l'Eclairage) Standard Illuminant C, representing average daylight from the total sky.

Color in the marked area of each peach was compared visually by one person with a series of ground color references under indirect daylight. These color references had a matte finish and were mounted in standard, plastic, 35-mm slide holders with a 1.3-cm hole punched in the center of each 5-cm, square color reference. Colorimenter readings of the color reference series, summarized in Table 1, were measured from the mounted series and, therefore, compensate for slight color effects due to the plastic. The first 13 color references in Table 1 correspond to the color standards used by the CTFA during 1982. The remaining 18 color references follow a uniform path through color space, beginning at a point similar in hue to reference one only lighter and ending at a point midway between color references 5 and 7. All visual comparisons and colorimeter measurements were made on unbrushed peaches.

Firmness. Ten peaches in each category per sample were tested for flesh firmness in the field using an Effe-gi fruit pressure tester (Model FT 327. Effe-gi, 48011, Aflonsine, Italy). Each fruit was tested on both pared cheeks using the 8-mm-diameter tip and an average firmness for each catetory was recorded. Since firmness was measured at the time of sampling, effects due to postharvest cooling were avoided.

Soluble solids and total titratable acid. Following the post-ripen color measurements, 3 to 5 peaches in each category were peeled and sliced. Composite samples of juice were tested for percentage of soluble solids. Total titratable acid was measured by titrating 10-ml aliquots of the composite juice with 0.1 N NaOH, using phenolphthalein as an indicator. Results are expressed as a theoretical equivalent weight of malic acid (5).

Taste and visual rating. A portion of the peaches used to measure soluble solids and total titratable acid was diced and placed in coded containers for tasting. The remaining intact peaches in each category were placed in coded boxes for inspection. A panel of 5 to 10 people rated each of the 3 categories per sample for taste and visual appearance using the following simplified scale: 1 = unacceptable, 2 = acceptable, and 3 = better than acceptable.

Results and Discussion

Average field firmness and preripen colorimeter results for the threshold and mature categories are summarized in Table 2. Comparing total average color measurements between threshold and mature categories, both the "L" and "b" coordinates are virtually the same and the "a" value shifts from −5.4 to −3.1. Peaches in the threshold categories clearly were more green than peaches in the mature categories. The lack of difference in "b" values indicates that the 2 categories had about the same degree of yellow.

Inspection of the average color values between cultivars shows a surprising degree of uniformity in ground color at threshold maturity. Calculation of differences among cultivars was complicated by unequal numbers of peaches. The "L", "a", and "b" color coordinates are all algebraic functions of the tristimulus "Y" value and, hence, cannot be considered as independent observations. Although variations in "b" value between cultivars were of the same magnitude as the variations in "a" value, color differences between threshold and mature categories were predominantly in "a" value. Therefore, grouping the 13 culti-

Table 2. Preripen color measurements and field firmness for fruit in the threshold and mature categories.

Cultivar	No. samples	Threshold category[z] n	Field firmness (N)	L	a	b	Mature category[z] n	Field firmness (N)	L	a	b
Blake	5	50	52.6	61.7	−5.7 bc	27.3	50	45.4	62.0	−4.0 cde	27.1
Camden	1	10	---	60.7	−5.7 bc	26.1	10	---	62.8	−4.6 e	27.0
Candor	1	10	46.9	63.4	−5.3 ab	27.1	10	48.5	63.7	−2.5 abc	28.2
Coronet	4	40	51.3	61.7	−5.3 ab	27.1	40	40.7	60.5	−2.2 ab	26.8
Dixired	1	10	61.4	60.3	−5.1 ab	25.0	10	50.7	59.9	−3.6 bcde	25.2
Harvester	4	40	48.2	58.7	−4.4 a	24.7	40	42.9	58.8	−2.9 abcd	24.9
Jefferson	3	30	49.2	63.6	−5.0 a	28.2	30	42.2	63.1	−3.1 abcd	27.6
Junegold	4	40	50.7	62.3	−4.4 a	25.8	40	44.0	61.9	−3.2 bcde	26.2
Loring	4	40	47.1	59.3	−6.0 bc	27.6	40	33.3	58.6	−2.2 ab	27.9
Magnolia	2	20	49.5	61.4	−7.0 d	26.3	20	41.4	62.2	−4.7 e	26.7
Redglobe	4	40	61.5	60.0	−5.1 ab	27.2	40	51.6	59.2	−1.7 a	26.6
Redhaven	4	40	56.0	61.8	−5.7 bc	25.8	40	48.7	61.8	−3.6 bcde	26.3
Rio Oso Gem	2	20	62.7	61.9	−6.7 cd	29.6	20	56.5	62.6	−4.1 de	29.5
Mean			52.7	61.2	−5.4	26.8		44.6	61.0	−3.1	26.8
(SE)			(1.1)	(0.1)	(0.1)	(0.1)		(1.2)	(0.2)	(0.1)	(0.1)

[z]Means with same letter are in the same class by Duncan's multiple range test, 5% level.

vars in Table 2 on the basis of threshold "a" value with no overlap yields 4 classes: 1) 'Junegold' and 'Harvester'; 2) 'Jefferson', 'Redglobe', 'Dixired', 'Candor', and 'Coronet'; 3) 'Camden', 'Blake', 'Redhaven', and 'Loring'; and 4) 'Rio Oso Gem' and 'Magnolia'.

Average field firmness for peaches in the threshold categories was 52.7 N compared to 44.6 N for the mature categories. Rood (7) reported flesh firmness levels for 5 cultivars ranging from about 49 N to 58 N, using a similar scale for identifying peaches of acceptable eating quality after ripening. Measurements made in 1981 of flesh firmness on a single cultivar ('Redglobe') randomly selected from commercial harvest bins in South Carolina showed a state-wide average of 55.4 N.

Postripen color measurements and maturity analyses for the threshold and mature categories are summarized in Table 3. Although the same numbers of samples per cultivar were measured after ripening, actual numbers of peaches were smaller due to spoilage during ripening. More variability in color readings was observed within each cultivar due to the appearance of blush in the measured area. Small quantities of pink or red coloration decreased "L" values and increased "a" values. Total color averages for the threshold and mature categories were similar, particularly in "a" and "b" values. Comparing preripen and postripen color in the threshold categories listed in Tables 2 and 3, most of the color change during ripening occurred in "a" value, going from −5.4 to +2.5. These results suggest

Table 3. Postripen color measurements and maturity analyses for fruit in the threshold and mature categories.

Cultivar	No. samples	Threshold category n	L	a	b	Mature category n	L	a	b
Blake	5	42	61.1	2.4	29.5	44	59.8	1.9	28.8
Camden	1	10	58.9	−1.5	26.6	10	58.1	0.1	27.1
Candor	1	9	61.6	2.9	27.3	9	58.8	4.4	28.9
Coronet	4	35	59.3	2.7	27.6	36	55.3	4.3	26.5
Dixired	1	8	56.7	6.3	25.1	8	55.0	1.3	26.1
Harvester	4	33	55.6	3.3	26.1	36	53.0	3.4	25.1
Jefferson	3	26	59.4	2.1	29.8	27	57.6	3.3	29.3
Junegold	4	39	57.4	4.2	27.1	40	56.3	3.6	26.7
Loring	4	36	60.1	0.3	29.2	38	56.4	1.6	27.6
Magnolia	2	19	61.3	0.7	26.5	20	59.3	0.4	27.5
Redglobe	4	27	60.7	4.2	29.3	35	56.1	4.5	27.3
Redhaven	4	35	57.9	2.7	28.0	30	57.4	2.1	27.0
Rio Oso Gem	2	15	61.0	1.3	31.9	15	58.0	3.8	30.3
Mean			59.2	2.5	28.2		56.8	2.8	27.4
(SE)			(0.2)	(0.1)	(0.1)		(0.2)	(0.1)	(0.1)

	Threshold (n = 39)	Mature (n = 39)
Soluble solids-% (SE)	10.8 (0.2)	10.7 (0.2)
Malic acid-g/10 ml juice (SE)	1.1 (0.0)	0.9 (0.0)
Soluble solids/acid (SE)	10.0 (0.3)	12.4 (0.5)
Taste rating (SE)	1.7 (0.1)	2.2 (0.1)
Visual rating (SE)	1.7 (0.1)	2.3 (0.1)

Table 4. Correlation coefficients between field firmness, postripen maturity indices, and preripen threshold color.[z]

	Correlation coefficient (r)								
	Field firmness	Soluble solids	Malic acid	Sol. solids /acid	Taste rating	Visual rating	Threshold L	Threshold a	Threshold b
Field firmness	---								
Soluble solids	0.13	---							
Malic acid	0.53*	0.29*	---						
Sol. solids/acid	−0.51*	0.05	−0.85*	---					
Taste rating	−0.56*	0.29*	−0.44*	0.53*	---				
Visual rating	−0.52*	0.11	−0.50*	0.50*	0.71*	---			
L	0.16	−0.04	0.00	0.03	−0.14	−0.12	---		
a	−0.69*	−0.04	−0.50*	0.46*	0.64*	0.62*	−0.33*	---	
b	0.22*	0.29*	0.20*	−0.06	0.05	0.07	0.30*	−0.38*	---

[z]For correlation coefficients involving field firmness, n = 114. For all others, n = 117.
*Significantly different from zero at 5% level.

that ground colors of different cultivars start from different points in color space, separated mainly by differences in "a" value, and follow trajectories during ripening which end in about the same region.

Taste ratings show that peaches in the threshold categories were judged slightly lower than the acceptable rating of 2, whereas mature category fruit were rated slightly higher than acceptable (Table 3). Selections of threshold categories were made conservatively to ensure minimum ground color levels. Mean soluble solids were similar, although the threshold categories contained more malic acid. Higher average soluble-solids-to-acid ratios for the mature categories concurs with previous reports where this ratio was found to increase steadily with increasing harvest maturity (8).

The relationships of field firmness, preripen ground color measurements, and postripen maturity indices were examined by computing standard correlation coefficients between all variables over all samples (Table 4). These results contain the variability inherent in 13 different cultivars of peaches. Similar measurements of the same sample size for a single cultivar would likely yield higher correlation coefficients. Field firmness correlated most highly with preripen "a" value. Taste panel evaluation had its highest correlation with visual rating, followed closely by that with "a" value. Correlations in both cases with the other 2 color parameters were poor. Unlike Rood's findings (7), the data in Table 4 show that measurements of ground color at harvest were a slightly better indicator of edible quality after ripening than field firmness. Differences were probably due to the method of color measurement.

Table 5. Visual matching of the color reference series with pre-ripen threshold colors and calculated best color reference match.

Cultivar	Visual color selection[z]	Closest color reference to threshold for L,a,b space	a,b plane	a axis	θ[y]
Blake	7,6	3,25	5,27	7,31	30,31
Camden[x]	3	3,24	5,26	7,31	6,29
Candor	27,31,8	26,25	5,27	(11),7	31,30
Coronet	6,7	3,25	5,27	(11),7	31,30
Dixired	3,7,2	23,24	5,25	(11),7	31,30
Harvester	7,31	23,22	5,26	10,9	7,31
Jefferson	7,8	27,26	5,29	11,7	7,31
Junegold	3,27,7	25,3	5,27	10,9	7,31
Loring	2,3,7	3,23	5,27	31,30	6,29
Magnolia	5	24,3	25,26	27,28	26,3
Redglobe	3,7	3,24	5,27	11,7	7,31
Redhaven	3,27,7	24,25	5,26	7,31	29,5
Rio Oso Gem	7	3,25	6,30	28,6	5,29

[z]Color references 10–12 not used for visual color selection.
[y]Angle between line drawn in "a,b" plane from color measurement to origin and the positive "a" axis.
[x]Color references 14–31 not used for visual color selection in Camden.

Ground color in the designated area of each fruit also was compared with the series of color references specified in Table 1. The most frequently selected color references for the threshold maturity peaches were references 7 and 3 (Table 5). Comparing the preripen threshold colors in Table 2 with each color reference measurement in Table 1, reference 7 is closest in "a" value to the total average. However, the "L" and "b" values of reference 7 indicate a lighter and more yellow shade than the average threshold peach color. Similarly, reference 3 is closest in "L" value to the total average, but is also more green and yellow than the actual threshold ground color.

Comparing color references 1–13 in Table 1 with threshold ground colors in Table 2, it is clear that these 2 groups lie in different regions of color space. For color references with "a" values in the same range as the 13 cultivars, −7 to −4, both "L" and "b" values are too large. The remaining color references follow a uniform path in color space from green (reference 14) to more yellow (reference 31), but this path does not intersect the region of actual peach ground colors. These data explain the difficulty experienced during visual matching of the color references with actual peach colors.

Optimum color matches for each cultivar were selected theoretically by calculation of the distance in Cartesian coordinates between the measured threshold color and each color reference, and selection of the reference producing the shortest distance (4). Results from calculations in "L", "a", and "b" space agree poorly with visual selections. Considering only the chromaticity component of color difference, results from calculations in the "a,b" plane also do not match the visual results. Clearly, the observer did not calculate minimum distances in color space as a basis for color matching. Since "a" values were a significant maturity factor, optimum selections were calculated considering only distances along the "a" axis. Though still not good, the calculated matches agree with the visual color selections better than the previous predictions. As a final comparison, the angle, θ, between a line drawn in the "a,b" plane from the measurement to the origin and the positive "a" axis, was calculated for each reference and threshold color. Calculated matches are comparable in effectiveness to predictions based only on "a" value.

These data can be used to specify a series of ground color references for peaches by defining a trajectory in color space which spans the region of colors in Table 2. Maintaining an even trajectory ensures uniform transitions between colors and avoids visual gaps evident with the CTFA color references. The data in Table 2 indicate a trajectory ranging from L = 61.1, a = −8.0, and b = 26.8 to L = 61.1, a = −1.0, and b = 26.8. Color references in this series would maintain a constant "L" and "b" value with varying "a" values, since our results indicate that this was the color parameter of predominant change during maturation and ripening.

Factors affecting peach ground color which need to be examined include harvest date, orchard location, cultural practices, and seasonal variations. However, variations in threshold ground color among the 13 cultivars tested were surprisingly small. This suggests that color variations due to orchard location and cultural practice might be similarly small. We feel that a single series of 5 to 10 color references uniformly spanning the range of preripened ground colors is preferable to a different color specification for each cultivar. Such a color series could accommodate cultivars not specifically measured with the colorimeter and allow adjustments due to the forementioned sources of variation. Further research is needed to assess the possibility of a single series of color references for all Southeastern cultivars and the applicability of these references to other production areas in the country.

Treatment of the peach surface prior to visual inspection must be considered during color reference specification. Color measurements reported there were made using dry, unbrushed peaches. Both factors affect diffuse reflectance from the peach surface.

Conclusion

Differences in ground color resulting from differences in maturity at harvest occurred mostly in the "a" coordinate, which increased during maturation and ripening. Ground color at harvest was a slightly better indicator of edible quality after ripening than flesh firmness. Measurements of ground color for peaches judged to be of threshhold maturity (i.e., minimum maturity for satisfactory ripening) were distributed narrowly and were separated into 4 classes of "a" value for the 13 cultivars tested. Color references used for grading in California did not match actual ground color measurements for peaches grown in South Carolina.

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