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Variability in Sugars, Acids, Firmness, and Color Characteristics of 12 Peach Genotypes

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Abstract. **A wide range of color, sugar, and acid composition was found among 12 peach *[Prunuspersica* (L.) Batsch] genotypes. Among the high-acid genotypes, a trend of increasing Hunter 'a' values, fructose, soluble solids concentration (SSC) : titratable acidity (TA) ratio, and decreasing TA and citric acid levels was noted with decreasing mesocarp firmness. Mesocarp firmness was correlated with both skin and flesh 'a' values within all genotypes. Among genotypes, the Hunter 'a'/firmness relationship varied. 'Elberta', a cultivar known to retain a greenish ground color, had a lower Hunter 'a' value when soft than did more recent releases such as 'Dixiland', 'Redhaven', and 'Suwanee'. 'Sam Houston', a low-acid cultivar, had lower TA and malic, citric, and quinic acid levels than the other cultivars. The dominant acid for all genotypes was malic (50% to 60% of total) with about equal amounts of citric and quinic. Soluble sugars included sucrose (54% of total), fructose (31%), and glucose (15%). 'Sam Houston' had lower SSC, a higher percentage of sucrose, lower levels of glucose and fructose, but the same relative sweetness values as the high-acid cultivars.**

Various compositional and visual attributes of diverse peach cultivars have been researched to establish easily applied characteristics to judge the proper harvest period. Ground color (skin or flesh), defined via the Hunter tristimulus 'a' parameter, and fruit firmness have been employed to judge the maturity of peaches (Delwiche and Baumgardner, 1983, 1985; Kader et al., 1982; Rood, 1957). Negative 'a' values indicate more relative greenness and positive 'a' values indicate more red or less green. Studies on 13 commercial fresh-market peaches indicated that at a preripe firmness of 52 N the 'a' value for ground color was distributed within a range of – 7.0 to – 4.4. At 45 N firmness, the range was – 4.7 to – 1.7 (Delwiche and Baumgardner, 1983, 1985). With clingstone peach cultivars, a wide range of flesh 'a' values (5.2 to 15.6) was reported for mature (firmness = 26 N) fruit (Kader et al., 1982).

Most reports on peach quality traits have focused on sugar content estimated from SSC in degrees Brix and on acid, as TA, or as pH (Delwiche and Baumgardner, 1983, 1985; Kader et al., 1982; Meredith et al., 1989; Rood, 1957). Others have measured individual sugars and acids (Meredith et al., 1989; Robertson et al., 1988; Wills et al., 1983). The major acids in peaches are malic, citric, and quinic. Sucrose has been reported as the major soluble sugar (54'% to 75% of total) with smaller amounts of glucose (9% to 21%), fructose (3% to 25%) and sorbitol (4% to 11%) (Meredith et al., 1989; Wills et al., 1983). The purpose of this study was to survey a diverse group of peach genotypes for color, firmness, organic acids, and soluble sugars.

Materials and Methods

Twelve early to late-maturing peach genotypes (Table 1) were employed in these studies. All were high-acid types except for 'Sam Houston'. Notable high-acid types were 'Elberta', 'Loring', and 'Redhaven'. 'Elberta' was an important cultivar until 1940, at which time improved commercial types became available (Meyers et al., 1989). 'Loring' is widely known as a high-quality midseason peach, and 'Redhaven' is the most widely planted cultivar in the world (Iezzoni, 1987).

Table 1. Peach genotypes used in study.

Genotype	Chilling requirement'	FDP[Y]	Ripe date'	Release date	State of origin
Harvester	750	92	15 June	1973	La.
Redhaven	950	95	16 June	1940	Mich.
Sam Houston	650	100	13 June	1965	Texas
Y5-64	550	105	14 June	---	Texas
Fireprince	850	105	22 June	1985	Ga.
Suwanee	650	106	18 June	1962	Ga.
Loring	750	118	10 July	1946	Mo.
Ouachita Gold	850	133	25 July	1981	La,
Dixiland	750	135	23 July	1962	Ga.
Elberta	850	136	27 July	1840	Ga.
Jerseyqueen	850	137	29 July	1964	N.J.
La Jewell	850	143	3 Aug.	1988	La.

'Chilling requirement in chill units determined by relative bloom time with respect to the standard cultivars: Texstar (550 chill units), Harvester (750 chill units), and Springold (850 chill units).
[Y]Fruit development period, no. days from full bloom until first commercial harvest at College Station, Texas.
'Date of first commercial harvest (20% of fruit firm ripe) in 1988.

Peaches were picked between June and August from the orchards at Texas A&M Univ. Research orchard in College Station. Fruit of each genotype were harvested from random locations on two trees. About 60 peaches of each genotype were picked, their color and texture measured as described below, and then grouped into four firmness classes. The peaches were stored in sealed plastic bags at »2C, and chemical analyses were carried out on one composite sample per firmness group the following day.

Color was measured using a Hunter LabScan calorimeter (Hunterlab, Reston, Vs.) with a l-cm-diameter specimen port. Before each use, the instrument was standardized to a white tile of known L, a, and b values. Peaches were neither washed nor brushed before being measured. Skin color was measured from an area of the peach judged to be least blushed. The skin was then removed and the flesh color measured from the same area. .

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Abbreviations: SSC, soluble solids concentration; TA, titratable acidity.

Texture was measured from the same area as flesh color, by use of an Effe-gi penetrometer (Effe-gi, 48011, Afolnsine, Italy) equipped with an 8-mm cylindrical plunger.

A composite sample of mesocarp tissue derived from five fruit grouped on the basis of firmness was homogenized using a blender, and the homogenate was filtered through cheesecloth to obtain the juice for chemical measurements. The filtered juice was partitioned into three subsamples. These were measured for percent SSC with a refractometer (Bausch and Lomb, Abbé) and for TA by titration with 0.1 N NaOH. Titration data are expressed as milliequivalents of anhydrous malic acid per milliliter of juice (meq H +/ml).

Sugars and organic acids were analyzed using the gas–liquid chromatographic method described by Marcy and Carroll (1982). Samples (3 ml) of juice filtrate were filtered through an activated Sep-pak C_{18} cartridge and freeze-dried before derivatization. Qualitative analysis of trimethylsilyl-oxime derivatives of organic acids and soluble sugars was accomplished by comparing retention times of unknown peaks to those of known standards. Quantification was by the internal standard method. Averages of three calibration standards determined at several concentrations were used as the relative response factors.

The fruit were grouped according to the following mesocarp firmness categories (FC): 1 = O-22 N, 2 = >22 N and ≤44 N, 3 = >44 N and ≤66 N, and 4 = >66 N. Firmness category 1 fruit were soft ripe, FC 2 were firm ripe, FC 3 corresponded to threshold maturity as described by Delwiche and Baumgardner (1983), and FC 4 fruit were considered immature. The mature category of Delwiche and Baumgardner (1983) is at the high extreme of FC 2 and the lower extreme of FC 3. Mean values of composite samples were used in all the statistical analyses.

Results and Discussion

Color. Ground color as opposed to the blush overcolor is considered to be well correlated with flesh firmness of fresh-rnarket peaches (Delwiche and Baumgardner, 1983, 1985) and contributes to the brightness of the fruit. With canning clingstone cultivars, the color of the flesh as determined by the 'a' value can be used as a measure of maturity (Kader et al., 1982). The less green (lower 'a' values) the color, the more mature the fruit. Among the peach cultivars studied, firmness was well correlated with 'a' values from both skin and flesh (Tables 2 and 3). The flesh values were less variable than those from the skin (Table 4), probably because of the red overcolor of the skin.

The "range in mean skin ground color 'a' for the cultivars surveyed was 3.1 to 10.3 (Table 4). The range is 2-fold greater than that reported by Delwiche and Baumgardner (1983) in their survey of 13 fresh-market cultivars and is similar to the differences among canning clingstone cultivars reported by Kader et al. (1982). 'Elberta', Y5-64, and 'Harvester' have been noted for greenish ground color when firm ripe, and this was reflected in lower skin 'a' values (Table 4). Generally, breeders have selected cultivars with a less green ground color while still firm enough to market. The cultivars examined here differed in color and in the rate of change in color with respect to firmness.

Organic acid composition. Over all genotypes, malic was the predominant acid (50% to 60% of total) with citric (20% to 25%) and quinic (20% to 25%) being present in lesser quantities (Table 5). Only citric acid levels and TA consistently decreased as firmness decreased (Table 2). These trends agree with previous work (Kader et al., 1982; Meredith et al., 1989; Wills et al., 1983), although Wills et al. (1983) reported a higher level (as percent of total acid) of citric acid (35%) and a lower level of quinic acid (20%) than we observed.

'Sam Houston', the low-acid cultivar, had lower TA than the high-acid peaches (2.1 vs. 8.7 H+ meq·ml^{-1}, and the highest SSC : TA ratio (6.0 vs. 1.6) of the cultivars assayed (Table 4). This cultivar had lower levels of all three acids than the average of the high-acid types: malic acid (5.0 vs. 8.4 mg·ml^{-1}), citric acid (1.1 vs. 3.5), and quinic acid (2.7 vs. 3.2). AIthough 'Elberta' and 'Fireprince' had levels of malic acid similar to the low-acid 'Sam Houston'. they had three to four times the TA level of 'Sam Houston'. 'Sam Houston', 'Fireprince', and 'La Jewell' were lower in TA than 'Loring' and 'Redhaven', two widely grown commercial cultivars. In addition, 'Fireprince' and 'Sam Houston' had lower and 'Suwanee' and 'Y5-64' had higher levels of malic acid than 'Loring' or 'Redhaven'.

The organic acid levels were well correlated with TA. The ratio of SSC to TA was negatively correlated with TA, malic acid, and citric acid levels (Table 3). A negative correlation between firmness and SSC : TA (– 0.48), reflecting an increase in SSC and a decrease in TA with decreasing firmness (i.e., ripening) was also reported by Delwiche and Baumgardner (1983). Malic acid content was correlated to skin yellowness (b) and skin brightness (L) values. These relationships have not been reported previously, although Delwiche and Baumgardner (1983) reported significant but low correlations between TA and 'a' (r = 0.50) and 'b' (r = 0.20) values.

Sugar composition. As with other studies (Long and Chism, 1987; Robertson et al., 1988; Wills et al., 1983), we found sucrose was the major soluble sugar (Table 5). The sucrose content of the peach genotypes examined ranged from 45% to 65% of total soluble sugars. In previous reports, glucose and fructose were found in about equal levels. In the present study,

Table 2. Mean value for fruit maturity variation in flesh color, firmness, and chemical composition of 11 high-acid peach cultivars.

Firmness category[z]	Color (CDM 'a' value) Skin	Flesh	Firmness (N)	TA (meq H+/ml)	Acid (mg·ml^{-1}) Malic	Citric	Quinic	SSC (°Brix)	Sugar (mg·ml^{-1}) Fructose	Glucose	Sucrose	Rel swt[y]	SSC : TA
4	3.5	4.8	75	10.1	8.9	4.4	3.6	13.5	41	22	79	17	1.4
3	5.8	7.6	56	8.9	8.3	3.4	3.2	13.2	47	24	81	18	1.6
2	8.4	9.3	36	8.7	8.9	3.6	3.4	14.3	43	22	76	17	1.7
1	13.0	11.4	16	7.8	8.1	2.9	3.3	15.0	56	25	75	19	2.1
Significance	***	***	***	*	NS	**	NS	NS	*	NS	NS	NS	**

[z]Firmness category: 1 = 0–22 N, 2 = >22 N and ≤44 N, 3 = >44 N and ≤66 N, 4 = >66 N.
[y]Rel swt = relative sweetness, sugar content weighted by sweetness relative to sucrose (1.00). Calculated as sum of sucrose content (×1.00), fructose content (×1.73), and glucose content (×0.74), divided by 10.
NS,*,**,***Regression analysis, nonsignificant and significant at P = 0.05, 0.01, and 0.001, respectively.

Table 3. Correlations[z] among firmness, chemical[y], and color[x] attributes in high-acid peach genotypes at four firmness stages.

Firmness	Skin a	−0.72
	Flesh a	−0.74
	Flesh L	0.58
	SSC : TA	−0.48
SSC	SSC : TA	0.54
TA	SSC : TA	−0.80
Malic	TA	0.77
	SSC : TA	−0.62
	Skin b	−0.49
	Skin L	−0.52
Citric	TA	0.79
	SSC : TA	−0.58
Quinic	TA	0.60

[z]All correlations significant at $P = 0.001$, n = 43.
[y]SSC, fructose, glucose, sucrose, relative sweetness, TA, malic acid, citric acid, quinic acid, and SSC : TA.
[x]a, b, and L values of flesh and skin.

Table 4. Firmness, ground color, SSC, and TA of 12 peach genotypes averaged over firmness categories.

Genotype	Firmness (N)	'a' color Skin	Flesh	SSC (°Brix)	TA[z]	SSC : TA
Dixiland	41	8.4	9.6	16.0	8.7	1.9
Elberta	46	3.1	5.1	14.0	7.5	1.9
Fireprince	55	7.6	9.2	13.8	5.7	2.4
Harvester	42	4.9	6.7	13.8	8.4	1.7
Jerseyqueen	53	7.3	9.8	8.0	10.5	0.8
LaJewell	54	8.8	10.7	10.5	6.9	1.5
Loring	46	5.5	7.4	16.5	9.9	1.7
Ouachita Gold	44	7.7	9.6	14.8	8.7	1.7
Redhaven	43	10.2	10.0	15.5	8.6	1.8
Sam Houston	42	10.3	7.6	12.7	2.1	6.0
Suwanee	51	8.1	7.1	14.0	10.7	1.3
Y5-64	52	3.6	6.6	13.0	10.6	1.3
Mean	47	7.2	8.2	13.5	8.1	2.1
					(8.7)[y]	(1.6)
LSD (0.05)	16	3.9	2.1	1.4	1.5	0.4

[z]TA, milliequivalents of anhydrous malic acid per milliliter of juice.
[y]Mean calculated without 'Sam Houston'.

the level of fructose for all genotypes was twice that of glucose (Tables 2 and 5). There was a general increase in SSC and sugar levels with the decrease in firmness, but this increase was significant only with fructose (Table 2). There were large differences in sugar levels, °Brix, and relative sweetness between the peach genotypes (Tables 4 and 5). 'Loring', 'Dixiland', and 'Redhaven' had the highest SSC but not the highest levels of fructose, glucose, sucrose, or relative sweetness.

SSC was not correlated with individual sugar levels or the composite relative sweetness (Table 3) because SSC values measured using a refractometer reflect the presence of all soluble optically active compounds including pectins, salts, acids, and sugars (Jacobs, 1944). A similar observation has been reported in citrus (Echeverria and Ismail, 1990).

Summary and Conclusion

A wide range of color and compositional components was observed in the peach genotypes examined. Ground color, as measured with the Hunter 'a' value, was well correlated with firmness, but genotypes differed in their firmness/Hunter 'a'

Table 5. Soluble sugar and acid composition of 12 peach genotypes averaged over firmness categories.

Genotype	Sugar (mg·ml⁻¹) Fructose	Glucose	Sucrose	Rel swt[z]	Acid (mg·ml⁻¹) Malic	Citric	Quinic
Dixiland	44	23	78	17	7.5	3.1	2.2
Elberta	38	18	70	15	6.0	2.7	2.3
Fireprince	29	17	70	13	4.8	2.2	2.2
Harvester	36	21	80	16	7.6	3.2	2.8
Jerseyqueen	55	23	65	18	9.7	3.9	2.8
LaJewell	59	24	90	21	6.9	1.6	2.4
Loring	48	23	75	18	8.8	3.3	3.9
Ouachita Gold	53	27	84	20	8.5	3.8	4.1
Redhaven	38	22	87	17	7.8	4.2	3.4
Sam Houston	34	16	96	17	5.0	1.1	2.7
Suwanee	52	26	87	20	12.5	4.8	4.3
Y5-64	50	27	81	19	12.1	5.2	5.3
Mean	44	22	81	17	8.1	3.2	3.2
					(8.4)[y]	(3.5)	(3.2)
LSD(0.05)	13	6	14	4	2.0	1.6	0.7

[z]Rel swt: sugar content weighted by sweetness relative to sucrose (1.00). Calculated as sum of sucrose content (×1.00), fructose content (×1.73), and glucose content (×0.74) and divided by 10.
[y]Mean calculated without 'Sam Houston'.

relationship. Peaches that have a green ground color when soft (<22 N), such as 'Elberta', had lower 'a' values. Most of the commercially grown cultivars were similar in sugar and acid content to 'Loring' or 'Redhaven'. 'Sam Houston', the low-acid peach, had a TA three to five times lower and a higher sucrose content than the high-acid cultivars. Individual organic acid contents were well correlated with TA. The sugar content or the relative sweetness index was not correlated with SSC. The differences between cultivars need to be characterized to better define the acceptable range of color and chemical components in particular types of cultivars (low-acid vs. high-acid types).

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