Kinsella, J. E.; Phillips, L. Structure: Function Relationships in Food Proteins: Film and Foaming Behavior. In *Food Protein: Structural and Functional Relationships*; Kinsella, J. E., Soucie, W. G., Eds.; American Oil Chemists' Society: Champaign, IL, 1989.
Klemacezwski, J.; Kang, Y. J.; Kinsella, J. E. Effects of Controlled Sulfitolysis of Bovine Serum Albumin on Droplet Size and Surface Area of Emulsions. *J. Agric. Food Chem.* **1989**, in press.
Kronman, M. J.; Robbins, F. M. Exposed and Buried Groups in Proteins. In *Fine Structure of Proteins and Nucleic Acids*; Fasman, G. D.; Timasheff, S. N., Eds.; Marcel Dekker: New York, 1970; p 271.
Leach, S. J.; Scheraga, H. A. Ultraviolet Difference Spectra and Internal Structure of Proteins. *J. Biol. Chem.* **1960**, *235*, 2827.
Lehrer, S. S. Perturbation of Intrinsic Protein Fluorescence. In *Biochemical Fluorescence: Concepts*; Chen, R. F., Edelhoch, H., Eds.; Marcel Dekker: New York, 1975; Vol. 2, p 487.
MacRitchie, F. Proteins at Interfaces. *Adv. Protein Chem.* **1978**, *32*, 283.
McKenzie, H. A. Effects of Changes in Environmental Conditions on the State of Association, Conformation and Structure. In *Milk Proteins: Chemistry and Molecular Biology*; McKenzie, H. A., Ed.; Academic Press: New York, 1970; Vol. 1, p 355.
Means, G. E. Feeney, R. E. *Chemical Modification of Proteins*; Holden-Day: San Francisco, 1970; p 214.
Melander, W.; Horvath, C. Salt Effects on Hydrophobic Interactions in Precipitation and Chromatography of Proteins: An Interpretation of Lyotropic Series. *Arch. Biochem. Biophys.* **1977**, *183*, 200.
Mita, T.; Nikai, K.; Hiraoka, T.; Matsue, S.; Matsumoto, H. Physicochemical Studies on Wheat Protein Foams. *J. Colloid Interface Sci.* **1977**, *59*, 172.
Mita, T.; Ishida, E.; Matsumoto, H. In Physicochemical studies on wheat protein foams. II Relationship between bubble size and stability of foams prepared with glutelin and gluten components. *J. Colloid Interface Sci.* **1978**, *64*, 143.
Phillips, L.; Haque, Z.; Kinsella, J. E. A Method for the Measurement of Foam Formation and Stability. *J. Food Sci.* **1987**, *52*, 1074.
Reddy, I. M.; Kella, N. K. D.; Kinsella, J. E. Structural and Conformational Basis of the Resistance of β-Lactoglobulin to Peptic and Chymotryptic Digestion. *J. Agric. Food Chem.* **1988**, *36*, 737.
Schulze, G. E.; Schirmer, R. H. *Principles of Protein Structure*; Springer-Verlag: New York, 1979.
Song, K. B.; Damodaran, S. Structure-Function Relationship of Proteins: Adsorption of Structural Intermediates of Bovine Serum Albumin at the Air-Water Interface. *J. Agric. Food Chem.* **1987**, *35*, 236.
Stainsby, G. Foaming and Emulsification. In *Functional Properties of Food Macromolecules*; Mitchell, J. R., Ledward, D. A., Eds.; Elsevier: London, 1986; p 315.
Teale, F. W. J. The Ultraviolet Fluorescence of Proteins in Neutral Solution. *Biochem. J.* **1960**, *76*, 381.
Thornton, J. M. Disulfide Bridges in Globular Proteins. *J. Mol. Biol.* **1981**, *151*, 261.
Turner, D. C.; Brand, L. Quantitative Estimation of Protein Binding Site Polarity. *Biochemistry* **1968**, *7*, 3381.
Walker, M. S.; Bednar, T. W.; Lumry, R. Exciplex Formation in Excited State of Indole. *J. Chem. Phys.* **1966**, *45*, 3455.
Walker, M. S.; Bednar, T. W.; Lumry, R. Exciplex Studies II. Indole and Indole Derivatives. *J. Chem. Phys.* **1967**, *47*, 1020.
Waniska, R. D.; Kinsella, J. E. Glycosylation of β-lactoglobulin and surface active properties. In *Food Proteins: Structure and Functional Relationships*; Kinsella, J. E., Soucie, W. G., Eds.; American Oil Chemists' Society: Champaign, IL, 1989.

Received for review November 1, 1988. Accepted March 23, 1989.

# Changes in Physical and Chemical Parameters Associated with Quality and Postharvest Ripening of Harvester Peaches

Filmore I. Meredith,* James A. Robertson, and Robert J. Horvat

Changes in the quality characteristics of Harvester peaches related to ripening for 1, 3, 6, and 7 days and at different maturity stages as determined by the use of color chips (grades) were correlated. Hunter values $L$ and $b$ had only slight change while $a$ values increased and hue angle ($\theta$) decreased with ripening as chip maturity increased. Firmness and titratable acid decreased as ripening progressed. As maturity (chip 3 and above) and days of ripening increased, soluble solids/acid ratio increased. No change was found in the total phenolics with increasing chip maturity; however, with increasing days, ripening (day 6 and above) increases were found. As chip maturity increased, malic acid increased, citric acid decreased, and succinic acid remained the same. Glucose (1.21 mg/100 g) and fructose (1.04 mg/100 g) remained the same as maturity increased. Interactions with chip maturity and days ripening were found with sucrose and sorbitol. The sensory evaluation panel rated the peaches acceptable or better for unripened peaches at maturity chip 6 and maturity chip 4 and above for ripened peaches.

An estimated 1163.3 million pounds of peaches were produced in the United States in 1985 (USDA, 1986). Major production centers include the Southeastern states, California, New Jersey, Pennsylvania, and Washington.

Appearance of skin color, flavor, volatiles, texture, sugar, and acid content are the key components that contribute to a high-quality fresh peach. Studies on these parameters that define quality in a peach have been reported in the literature (Robertson et al., 1988; Shewfelt et al., 1987; Delwiche and Baumgardner, 1983; Kader et al., 1982; Watada et al., 1979; Spencer et al., 1978). These reports provide only a partial description of chemical and physical changes occurring in relation to quality. Because of this, it has not been possible to adequately define peach quality in relation to consumer acceptance. A better understanding of chemical changes in the peach that have positive and negative effects on organoleptic acceptance would facilitate the development of improved cultivars and enhance the postharvest preservation of quality (Dull and Hulme, 1971).

R. B. Russell Agricultural Research Center, USDA—ARS, P.O. Box 5677, Athens, Georgia 30613.

A major problem associated with inferior quality is harvesting fruit that are immature. Rood (1957) reported that peaches left to ripen on the tree for as long as possible will have the best quality. However, tree-ripened fruit are softer, do not ship well, and have reduced shelf life (Shewfelt et al., 1987). Therefore, a trade-off must be made by the grower between optimum quality and the requirements for fresh market sales.

This preliminary report compares firmness, color, chemical composition, volatile flavor constituents, and sensory evaluation of fresh peaches and peaches ripened for 7 days.

## MATERIAL AND METHODS

**Peaches.** Fruit of Harvester, a commercial quality, round, yellow, freestone melting flesh peach with fine texture (Ferree et al., 1983) were harvested from the University of Georgia Agronomy Farm. The peaches were immediately transported to the laboratory and sorted into six color grades against standard color chips (Delwiche and Baumgardner, 1985). The fruit were not treated with fungicide.

**Ripened Peaches.** Peaches from each of the six color chip maturity groups were placed into a ripening chamber that was maintained at 21 °C and 85% relative humidity. Fruit were removed from the ripening chamber for determination of external color, firmness, and chemical analysis after 1, 3, 6, and 7 days of ripening. Sensory evaluation of the peaches was conducted at the beginning of the experiment and after ripening for 7 days.

**External Color.** Ground color measurements were made with a Hunter color difference meter, Model D25M-2 (Hunter Lab, Fairfax, VA), calibrated with white plate C210216 ($L$ = 92.3, $a$ = −1.0, $b$ = +1.1). Hunter color difference readings were taken on 15 peaches from each maturity group. The first color measurement was made on the greenest point of the peach cheek of each fruit, with each successive measurement being taken 90° from the last reading. Four Hunter color difference measurements were taken and averaged for each peach. The Hunter color data were converted to hue angle $\theta$, where $\theta = \tan^{-1}(b/a)$ (Little, 1975).

Firmness was determined on two sides of the 15 peaches used in the color determination with a Magness-Taylor fruit pressure tester, Model 30A (0–133 N) or a Model 10B (0–44 N) (Ballauf Man, Laurel, MD), equipped with an 8-mm plunger. The model fruit tester used depended on the maturity of the peaches and their degree of firmness. The exocarp on the area to be pressure-tested was carefully removed from the peach with a razor blade just before puncturing with the plunger.

**Chemical Analysis.** Fifteen peaches from each maturity category were divided into three replications of five fruit each. The five fruit were sliced, the pit was removed, and the slices were ground to a puree in a Waring blender. Duplicate analyses were carried out on all. Total solids, pH, and titratable acidity were determined on the fresh ground puree (Robertson et al., 1988). Individual sugars were determined by HPLC (Meredith et al., 1988), total phenolics were determined by the method of Singleton and Rossi (1965), and organic acids were determined by the procedure of Chapman and Horvat (1988). The organic acid sample was injected into a Perkin-Elmer (Norwalk, CT) Sigma 300 capillary gas chromatograph equipped with a flame ionization detector and a split injector. Separation was on a 15 m × 0.25 mm (i.d.) capillary column (J & W Scientific, Folsom, CA) coated with DB-1 (methylsilicone) with a film thickness of 0.25 μm. The starting oven temperature of the GC was 150 °C, which was held for 4 min. After this initial time the oven temperature was increased at 4 °C/min to 192 °C, held for 30 s, and then increased at 10 °C/min to 240 °C and held for 7 min. Injector temperature was 230 °C, and detector temperature was 240 °C. Gas flow through the column was 1 mL/min helium.

**Mass Spectral Analysis.** Three peaches were cut in half and the pits removed. The peach tissue was cut into small pieces, and 100 g of the diced tissue was placed into a Waring blender with 200 mL of distilled water and macerated for 3 min at medium speed. The resulting slurry was placed in a 3-L round-bottomed flask with an additional 500 mL of distilled water. The flask was connected to a modified Likens and Nickerson steam distillation continuous hexane extraction apparatus (Shultz et al., 1977), and the hexane and peach macerate were boiled for 4 h at 120 mmHg pressure. The hexane extract was collected and reduced by a stream of purified $N_2$ gas at 45 °C to a 20-μL volume. Analysis was performed with a Perkin-Elmer Model 300 gas–liquid chromatograph equipped with a cold on-column injector. Sample volumes ranging from 0.5 to 1.0 μL were injected. The chromatograph was connected by a heated transfer line to an Extrel C50/400 mass spectrometer (Pittsburgh, PA). Separation of the flavor constituents was made on a 20 m × 0.32 mm (i.d.) fused silica capillary column coated with silicone GE SE-54. A carrier inlet pressure of 0.6 kg/cm$^2$ was used. The oven temperature was programmed from 50 to 220 °C at 3 °C/min and held at the upper temperature for 30 min. Conditions for the mass spectrophotometer were ion source temperature 150 °C, scan rate 200 μm/s, ionizing voltage 70 eV, and ion source pressure 2 × $10^{-5}$ Torr. Compounds were identified by comparison of their mass spectra and GLC retention times with those of known standards. Compounds identified solely on the basis of comparison of their mass spectra with standards in the literature are considered "tentatively identified".

**Table I. Hunter $L$, $a$, $b$, and Hue Angle of Outer Skin Color of Harvester Peaches Ripened at 21 °C and 85% Humidity for 0, 1, 3, 6, and 7 Days**

| | maturity chip | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Sx[a] |
| | | | | Day 0 | | | |
| $L$ | 72.5$^{zb}$ | 74.2$^{z}$ | 74.1$^{z}$ | 72.5$^{z}$ | 71.4$^{z}$ | 55.4$^{z}$ | 3.1 |
| $a$ | −8.3$^{zb}$ | −3.1$^{z}$ | −1.9$^{z}$ | 5.1$^{z}$ | 8.5$^{z}$ | 25.9$^{z}$ | 3.4 |
| $b$ | 32.0$^{zb}$ | 34.2$^{z}$ | 34.9$^{z}$ | 34.4$^{z}$ | 33.7$^{z}$ | 24.6$^{z}$ | 2.8 |
| $\theta$[c] | 104.4$^{zb}$ | 94.7$^{z}$ | 92.7$^{z}$ | 80.9$^{z}$ | 75.4$^{z}$ | 43.4$^{z}$ | 5.1 |
| | | | | Day 1 | | | |
| $L$ | 73.6$^{zb}$ | 74.7$^{z}$ | 75.4$^{z}$ | 76.5$^{z}$ | 74.4$^{z}$ | | 3.4 |
| $a$ | −6.8$^{zb}$ | −4.7$^{z}$ | 1.9$^{z}$ | 0.1$^{z}$ | 6.5$^{z}$ | | 5.5 |
| $b$ | 32.8$^{zb}$ | 34.4$^{z}$ | 36.0$^{z}$ | 36.3$^{z}$ | 35.1$^{z}$ | | 2.1 |
| $\theta$[c] | 101.8$^{zb}$ | 97.8$^{z}$ | 86.8$^{z}$ | 89.8$^{z}$ | 79.4$^{z}$ | | 9.3 |
| | | | | Day 3 | | | |
| $L$ | 73.8$^{zb}$ | 76.0$^{z}$ | 76.1$^{z}$ | | | | 3.4 |
| $a$ | −5.5$^{zb}$ | −3.2$^{z}$ | 0.2$^{z}$ | | | | 3.1 |
| $b$ | 33.4$^{zb}$ | 35.7$^{z}$ | 36.5$^{z}$ | | | | 2.1 |
| $\theta$[c] | 99.4$^{zb}$ | 94.9$^{z}$ | 89.5$^{z}$ | | | | 6.5 |
| | | | | Day 6 | | | |
| $L$ | 73.9$^{zb}$ | 76.0$^{z}$ | 74.6$^{z}$ | 74.2$^{z}$ | | | 4.1 |
| $a$ | −2.1$^{zb}$ | 1.8$^{y}$ | 10.3$^{y}$ | 10.0$^{y}$ | | | 3.8 |
| $b$ | 34.5$^{zb}$ | 35.8$^{z}$ | 37.3$^{z}$ | 37.7$^{z}$ | | | 3.3 |
| $\theta$[c] | 93.3$^{yb}$ | 87.1$^{y}$ | 74.5$^{y}$ | 75.0$^{y}$ | | | 6.2 |
| | | | | Day 7 | | | |
| $L$ | 76.0$^{z}$ | 74.5$^{z}$ | 74.9$^{z}$ | 72.9$^{z}$ | 68.4$^{z}$ | | 6.3 |
| $a$ | −0.2$^{yb}$ | 4.4$^{y}$ | 7.9$^{y}$ | 12.8$^{y}$ | 20.2$^{y}$ | | 5.4 |
| $b$ | 35.7$^{zb}$ | 35.9$^{z}$ | 36.8$^{z}$ | 37.2$^{z}$ | 34.5$^{z}$ | | 3.5 |
| $\theta$[c] | 90.3$^{yb}$ | 83.1$^{y}$ | 77.6$^{y}$ | 70.7$^{y}$ | 59.6$^{y}$ | | 9.2 |

[a] Standard error of mean. [b] Mean separation of day 0 compared to day 1, day 3, day 6, and day 7; values with different letters significant at the $P < 5\%$ level; values with the same letter nonsignificant. [c] Hue angle ($\theta$) (degrees) = $\tan^{-1}(b/a)$, where $a$ and $b$ are Hunter values.

**Sensory Evaluation.** Five peaches from each of the maturity grades were washed, peeled, sliced into small pieces, and placed into coded cups with sealed lids for evaluation. A 14-member taste panel judged the peach tissue for acceptability. The categories used to judge the peach tissue were unacceptable = 1, poor = 2, acceptable = 3, good = 4, and excellent = 5.

**Statistical Analysis.** The data were analyzed by the General Linear Models program of the Statistical Analysis System (SAS) for personal computers (SAS Institute, 1985). Where the interaction of chip maturity and day of ripening was significant a response surface analysis was performed to express this interaction (Little and Hills, 1978).

## RESULTS AND DISCUSSION

External skin color of Harvester peaches is given in Table I as Hunter $L$, $a$, $b$, and $\theta$ values. As chip maturity increased, $a$ values increased significantly ($P < 0.01$) while

**Table II. Means of Firmness, Acid, and Total Phenolics in Harvester Peaches Ripened at 21 °C and 85% Humidity for 0, 1, 3, 6, and 7 Days**

| | maturity chip | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Sx[a] |
| **Day 0** | | | | | | | |
| firmness[b] | 76.6[zc] | 60.4[z] | 58.2[z] | 42.4[z] | 51.4[z] | 27.5[z] | 9.1 |
| acid[d] | 0.94[zc] | 0.94[z] | 0.95[z] | 0.89[z] | 0.86[z] | 0.86[z] | 0.04 |
| total phenolics[e] | 249[zc] | 243[z] | 273[z] | 208[z] | 196[z] | 230[z] | 19.0 |
| soluble solids[f] | 12.42[zc] | 13.2[z] | 13.6[z] | 13.6[z] | 12.8[z] | 13.5[z] | 0.8 |
| soluble solids/acid | 13.2[zc] | 14.0[z] | 14.3[z] | 15.3[z] | 14.9[z] | 15.7[z] | 0.9 |
| **Day 1** | | | | | | | |
| firmness[b] | 73.9[zc] | 65.7[y] | 51.8[y] | 55.0[y] | 40.8[y] | | 9.2 |
| acid[d] | 0.88[zc] | 0.90[z] | 0.84[y] | 0.92[z] | 0.83[z] | | 0.06 |
| total phenolics[e] | 246[zc] | 237[z] | 265[z] | 233[z] | 235[z] | | 20.9 |
| soluble solids[f] | 12.2[z] | 12.8[z] | 13.4[z] | 12.9[z] | 13.0[z] | | 1.0 |
| soluble solids/acid | 3.9[zc] | 14.2[z] | 15.9[y] | 14.0[z] | 15.6[z] | | 1.3 |
| **Day 3** | | | | | | | |
| firmness[b] | 67.3[yc] | 53.7[y] | 39.8[y] | | | | 8.4 |
| acid[d] | 0.86[yc] | 0.93[z] | 0.86[z] | | | | 0.04 |
| total phenolics[e] | 203[zc] | 243[z] | 216[y] | | | | 15.2 |
| soluble solids[f] | 11.8[zc] | 13.2[z] | 13.1[z] | | | | 1.0 |
| soluble solids/acid | 13.7[zc] | 14.2[z] | 15.2[y] | | | | 0.8 |
| **Day 6** | | | | | | | |
| firmness[b] | 59.4[yc] | 37.7[y] | 10.0[y] | 9.1[zy] | | | 9.2 |
| acid[d] | 0.95[zc] | 0.91[z] | 0.77[y] | 0.78[y] | | | 0.05 |
| total phenolics[e] | 255[zc] | 308[y] | 349[y] | 300[y] | | | 18.1 |
| soluble solids[f] | 12.0[zc] | 12.8[z] | 13.0[z] | 12.9[z] | | | 0.9 |
| soluble solids/acid | 12.6[yc] | 14.0[z] | 16.9[y] | 16.5[y] | | | 1.0 |
| **Day 7** | | | | | | | |
| firmness[b] | 48.8[yz] | 27.6[y] | 17.8[y] | 16.4[zy] | 2.5[y] | | 9.2 |
| acid[d] | 0.91[zc] | 0.92[z] | 0.81[y] | 0.77[y] | 0.69[y] | | 0.4 |
| total phenolics[e] | 322[yc] | 292[y] | 283[z] | 256[y] | 267[y] | | 17.8 |
| soluble solids[f] | 12.2[z] | 12.1[z] | 12.9[z] | 12.6[z] | 13.5[z] | | 0.9 |
| soluble solids/acid | 13.4[yc] | 13.2[z] | 15.9[y] | 16.3[y] | 19.6[y] | | 1.1 |

[a] Standard error of mean. [b] Newtons. [c] Mean separation of day 0 compared to day 1, day 3, day 6, and day 7; values with different letters significant at the $P < 5\%$ level; values with the same letters nonsignificant. [d] Grams/100 g, reported as malic acid. [e] Micrograms per gram. [f] Grams/100 g.

$L$ and $b$ values were not significantly different except for maturity chip 6 day 0. Values for $\theta$, which represent $a$ and $b$ values as one value with $\pi r$ (180°) being green, $\pi r/2$ (90°) being yellow, and $0r$ (0°) being red (Little, 1975), were found to decrease. Changes in $a$ and $\theta$ show that peach ground color was changing from green to yellow to red as maturity increased. In comparing $L$, $a$, $b$, and $\theta$ for day 0 to day 1 and day 3, little significant change was found with ripening; however, a significant difference was found with $a$ values for day 6 and day 7. Deterioration of the fruit occurred for day 1, maturity chip 6; day 3, maturity chips 4–6; day 6, maturity chips 5 and 6; and day 7, maturity chip 6 so that external color, firmness, and chemical analysis could not be carried out. A sufficient number of fruit, however, were available for sensory evaluation for day 7 with all six of the maturity chips.

Flesh firmness, acid content, total phenolics concentration, soluble solids, and soluble solids/acid ratio of Harvester peaches ripened for 0, 1, 3, 6, and 7 days are shown in Table II. Firmness was found to decrease as maturity increased. A firmness measure of 13 N (3 lb) or lower is considered acceptable for eating (Heller, 1952). Peaches of maturity chips 1–3 did not develop acceptable firmness even after 7 days. In general, the acid concentration remained the same from maturity chip 1 through maturity chip 6 for day 0, 1, and 3. Acid levels for day 6 and 7 after maturity chip 2 were found to decrease. In comparing the acid content of day 0 to fruit ripened for 3, 6, and 7 days, significant differences were present in Harvester peaches at the later maturity chips (3 and above). Total phenolic concentration remained about the same until 6 and 7 days of ripening. Significant increases in the total phenolic level were found after this. Soluble solids ranged from 12.2 to 13.6 g/100 g. The soluble solids/acid ratio did not change significantly until maturity chip 3 when compared with day 0 and day 7. After this stage of maturity, the soluble solids/acid ratio increased. It was reported (Deshpande and Salunkhe, 1964) that peaches containing a soluble solids/acid ratio of 15.1 or above when harvested would ripen into high-quality fruit. This is substantiated by our data as maturity chips 1 and 2 did not ripen into quality fruit. Maturity chip 3 appears to be the break point for ripening.

**Table III. Means of Organic Acids Present in Harvester Peaches at Six Different Maturity Levels and 0, 3, and 7 Days of Ripening**

| | maturity chip | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Sx[a] |
| **Day 0** | | | | | | | |
| malic acid[b] | 0.35[zc] | 0.39[z] | 0.59[z] | 0.58[z] | 0.52[z] | 0.59[z] | 0.1 |
| citric acid[b] | 0.45[zc] | 0.39[z] | 0.29[z] | 0.30[z] | 0.28[z] | 0.23[z] | 0.08 |
| **Day 3** | | | | | | | |
| malic acid[b] | 0.36[zc] | 0.35[z] | 0.58[z] | | | | 0.1 |
| citric acid[b] | 0.43[zc] | 0.40[z] | 0.23[z] | | | | 0.08 |
| **Day 7** | | | | | | | |
| malic acid[b] | 0.36[zc] | 0.38[z] | 0.55[z] | 0.48[y] | 0.44[z] | | 0.1 |
| citric acid[b] | 0.40[zc] | 0.39[z] | 0.21[z] | 0.19[y] | 0.20[z] | | 0.07 |

[a] Standard error of mean. [b] Grams/100 g. [c] Mean separation of day 0 compared to day 3 and day 7; values with different letters significant at the $P < 5\%$ level; values with the same letter nonsignificant.

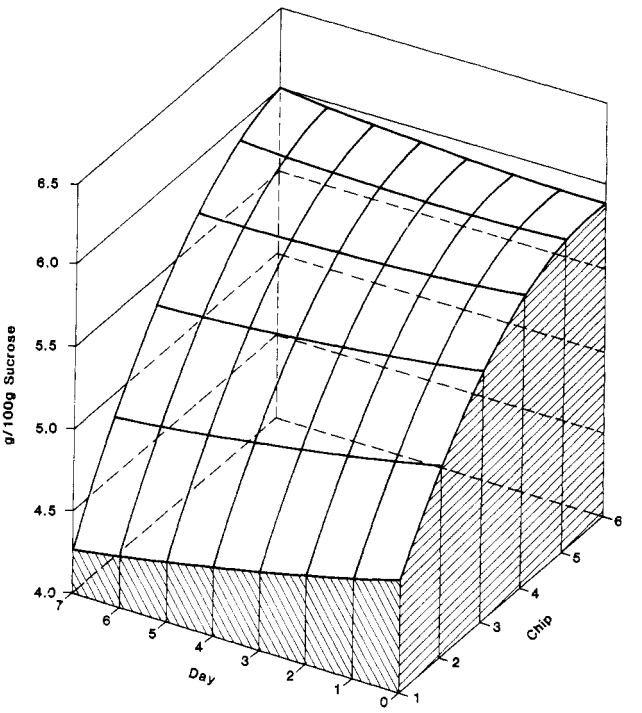


**Figure 1.** Sucrose concentration compared to days ripened at 21 °C and 85% relative humidity and maturity chip at harvest.

Organic acids that showed significant differences in Harvester peaches are shown in Table III. As maturity increased, citric acid concentrations decreased and malic acid increased. Ripening had no significant effect on acids in peaches of maturity chip 1–3 but decreased in peaches of maturity chips 4 and 5. Succinic acid, which had a concentration of 0.05 g/100 g, was not significantly different with respect to maturity chip or to days ripening. All of the data presented in Tables I–III were linear and

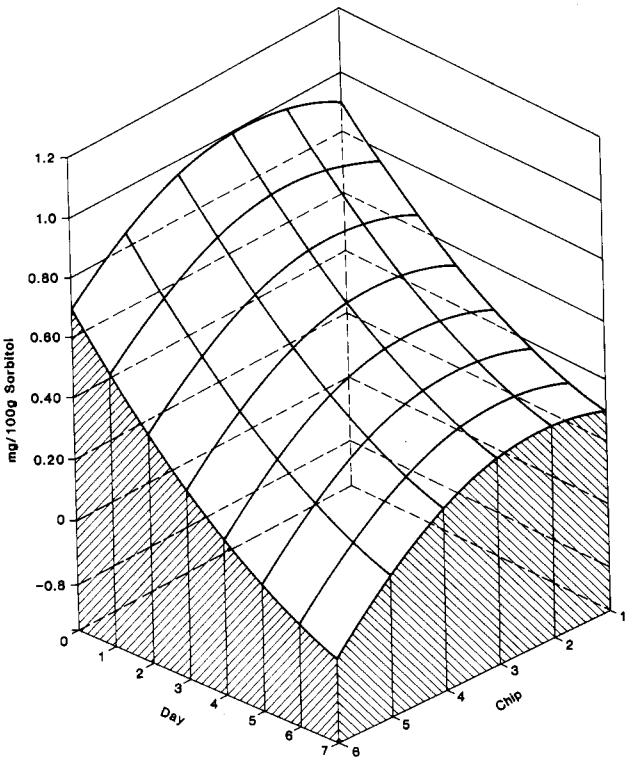


**Figure 2.** Surface analysis of sorbitol concentration compared to days ripened at 21 °C and 85% relative humidity.

did not interact with chip and day.

Glucose (1.21 mg/100 g) and fructose (1.04 mg/100 g) concentrations showed no significant differences as maturity chip increased, however. As days of ripening increased (days 6 and 7, maturity chips 1 and 2) glucose (1.51 mg/100 g) and fructose (1.26 mg/100 g) levels significantly increased while maturity chips 3–7 had no significant change in glucose (1.32 mg/100 g) and fructose (1.06 mg/100 g) levels. An additional sugar present in the Harvester peaches was sucrose and the glucose alcohol sorbitol. Significant interactions with chip maturity and days ripening were found with sucrose and sorbitol. A predicted response surface for sucrose (Figure 1) showed that for maturity chip 1 through maturity chip 3 as days ripening increased, sucrose levels decreased. However, as chip maturity increased (chip 4 and above), sucrose concentrations became greater as days ripening increased. Sucrose concentration did not go above 6.0 g/100 g. The response surface for sorbitol (Figure 2) presented a different pattern than sucrose for as chip maturity and day ripening increased sorbitol concentration decreased.

**Table IV. Means of the Sensory Evaluation Panel on Harvester Peaches Compared on Day 0 and after 7 Days of Ripening at 21 °C and 85% Humidity**

| | maturity chip | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | Sx[a] |
| day 0 | 1.1[zb] | 1.5[z] | 1.7[z] | 2.3[z] | 2.8[z] | 3.2[z] | 0.26 |
| day 7 | 1.1[z] | 2.4[y] | 2.4[y] | 3.6[y] | 3.7[y] | 4.4[y] | 0.21 |

[a] Standard error of mean. [b] Mean separation of day 0 compared to day 7; values with different letters significant at the $P < 5\%$ level; values with the same letter nonsignificant.

Comparison of gas–liquid chromatograms from volatile concentrates of Harvester peaches at maturity chips 2 and 6 day 0 are presented in Figure 3. Maturity chip 2 contained only $C_{23}$ and $C_{25}$ hydrocarbons while maturity chip 6 contained several different types of chemical constituents related to peach flavor. Three specific chemical regions were found in the chromatogram of maturity chip 6: the hexenal–hexenol, linalool–nonanal, and δ-decalactone that were not found in maturity chip 2. The isomer of dimethyldecanaphthalene was only tentatively identified since no authentic sample of this compound was available.

Sensory panel mean scores (Table IV) ranged from 1.1 for maturity chip 1 to 3.2 for maturity chip 6 for day 0 and 1.1 for maturity chip 1 to 4.4 for maturity chip 6 for day 7. Scores of 3.0 or above were needed for the fruit to be judged as acceptable. The slopes for each of the two lines

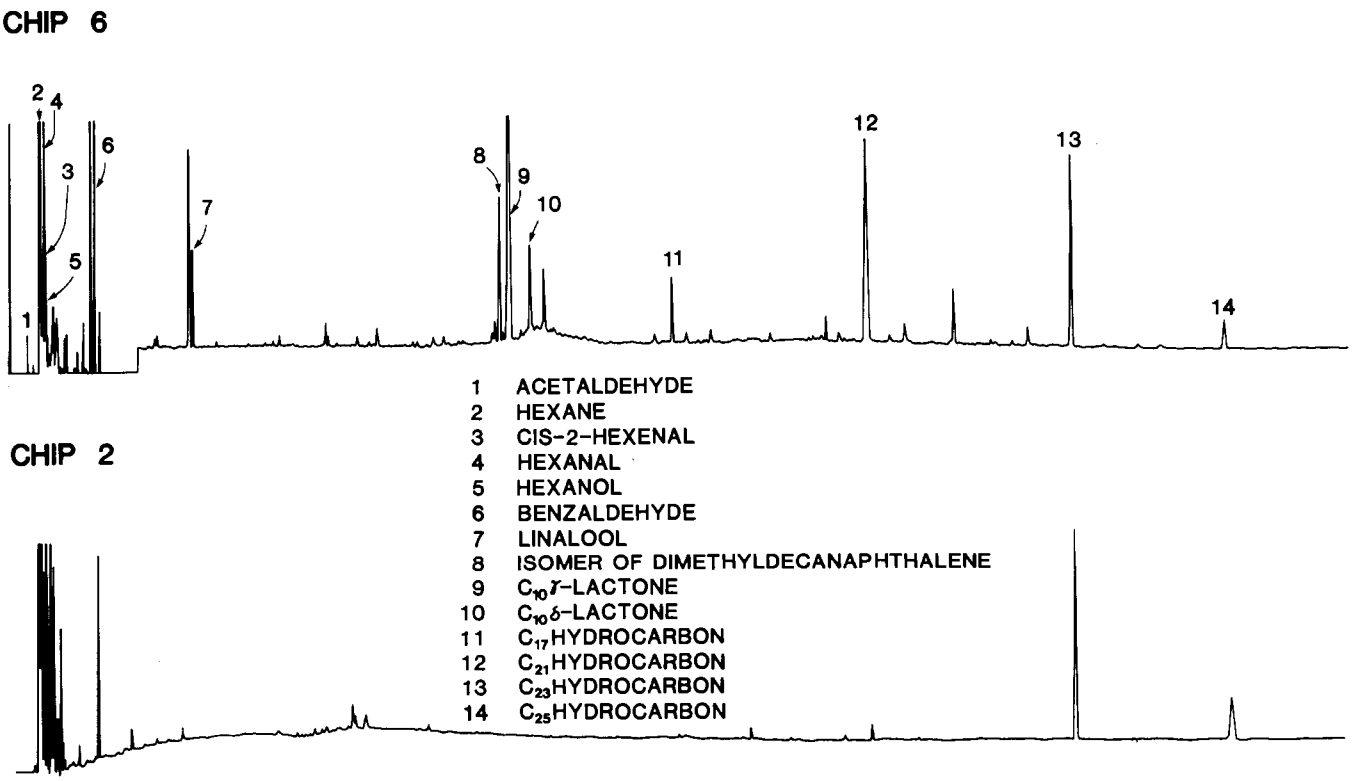


**Figure 3.** Comparison of flavor components in Harvester peaches at maturity chip 2 and maturity chip 6 at day 0.

for days 0 and 7 were linear and significantly different from each other. Panel scores indicated that Harvester peaches ripened for 7 days were preferred over peaches not ripened. Maturity chips 1–3 were immature and did not ripen to desert quality.

## CONCLUSIONS

Harvester peaches that were less than maturity chip 3 did not ripen as the acid concentration did not decrease, the soluble solids/acid ratio did not increase, the ground color of the fruit remained green, and the fruit remained firm. Peaches ripened for 7 days had a decrease in acid concentration and increases in sucrose and volatile components related to flavor, and the ground color went from green to yellow with the development of a red blush. As the acid, sucrose, and volatile concentrations changed in the maturing fruit, the sensory panel scores and their preference for this fruit increased. The increases in sucrose concentration, decrease in acid concentration, and the increase in volatile components appear to be changes that affected the sensory panel rating of the fruit acceptable or better. These changes in the chemical composition of the fruit are interrelated and play an important part in determining fruit quality. Additional studies will be required to relate chemical components to consumer acceptance so that peaches are harvested at the best maturity stage for shipping. This will allow the consumer to obtain high-quality peaches in the market place.

## ACKNOWLEDGMENT

We thank Judy Davis and Mike Jackson for conducting the chemical analysis and Ruel Wilson for the statistical analysis.

**Registry No.** Citric acid, 77-92-9; malic acid, 6915-15-7; succinic acid, 110-15-6; glucose, 50-99-7; fructose, 57-48-7; sucrose, 57-50-1; sorbital, 50-70-4; acetaldehyde, 75-07-0; hexane, 110-54-3; *cis*-2-hexenal, 16635-54-4; hexanal, 66-25-1; hexanol, 25917-35-5; benzaldehyde, 100-52-7; linalool, 78-70-6; dimethyldecanaphthalene, 28777-88-0; γ-decalactone, 706-14-9; δ-decalactone, 705-86-2.

## LITERATURE CITED

Chapman, G. W.; Horvat, R. J. The Determination of Nonvolatile Acids and Sugars from Fruits and Sweet Potato Extracts by Capillary and GLC/MS. Submitted for publication in *J. Agric. Food Chem.* 1988.

Delwiche, M. J.; Baumgardner, R. A. Ground Color Measurements of Peaches. *J. Am. Soc. Hortic. Sci.* **1983**, *108*, 1012–1016.

Delwiche, M. J.; Baumgardner, R. A. Ground Color as a Peach Maturity Index. *J. Am. Soc. Hortic. Sci.* **1985**, *110*, 53–57.

Deshpande, P. B.; Salunkhe, D. K. Effect of Maturity and Storage on Certain Biochemical Changes in Apricots and Pears. *Food Technol.* **1964**, *18*, 1195–1198.

Dull, G. G.; Hulme, A. C. Quality. In *The Biochemistry of Fruits and Their Products*; Hulme, A. C., Ed.; Academic Press: New York, 1971; Vol 2.

Ferree, M. E.; Okie, W. R.; Gambrell, C.; Ridley, J.; Brittain, J.; Cain, D.; Baumgardner, R. A.; Savage, E. F. Varieties. In *Peach Growers Handbook 1*; Feree, M. E., Burtrand, P. F., Eds.; G.E.S. Handbook #1: Georgia Cooperative Extension Service, University of Georgia: Athens, GA, 1983.

Heller, M. H. *Handling, Transportation, Storage, and Marketing of Peaches*; USDA Bibliographical Bulletin No. 21: U.S. GPO: Washington, DC, 1952; pp 1–105.

Kader, A. A.; Heintz, C. M.; Chordas, A. Postharvest Quality of Fresh and Canned Clingstone Peaches as influenced by Genotypes and Maturity at Harvest. *J. Am. Soc. Hortic. Sci.* **1982**, *107*, 947–951.

Little, A. A Research Note on a Tangent. *J. Food Sci.* **1975**, *40*, 410–411.

Little, T. M.; Hills, F. J. Correlation and Regression for More Than Two Variables: Response Surfaces. In *Agricultural Experimentation and Design and Analysis*; Wiley: New York, 1978.

Meredith, F. I.; Thomas, C. A.; Snook, M. E.; Himmelsbach, D. S.; van Helbeek, H. Soluble Carbohydrates, Oligosaccharides and Starch in Lima Bean Seeds. *J. Food Sci.* **1988**, *53*, 768–771.

Robertson, J. A.; Meredith, F. I.; Scorza, R. Characteristics of Fruit from High and Low Quality Peach Cultivars. *J. Am. Soc. Hortic. Sci.* **1988**, *23*, 1032–1034.

Rood, P. Development and Evaluation of Objective Maturity Indices for California Freestone Peaches. *Proc. Am. Soc. Hortic. Sci.* **1957**, *70*, 104–112.

SAS Institute Inc. *SAS/STAT Guide for Personal Computers, Version 6 Edition*; Joyner, S. P., Ed.; SAS Institute: Cary, NC, 1985.

Shewfelt, R. L.; Myers, S. C.; Resurreccion, A. V. A. Effect of Physiological Maturity at Harvest on Peach Quality During Low Temperature Storage. *J. Food Qual.* **1987**, *10*, 9–20.

Shultz, T. H.; Flath, R. A.; Eggling, S. B.; Teranishi, R. Isolation of Volatile Components from a Model System. *J. Agric. Food Chem.* **1977**, *25*, 446–449.

Singleton, V. L.; Rossi, J. A. Colorimetry of Total Phenolics with Phosphomolybdic-phosphotungstic Acid Reagent. *Am. J. Vitic.* **1965**, *16*, 144–158.

Spencer, M. D.; Pangborn, R. M.; Jennings, W. G. Gas Chromatographic and Sensory Analysis of Volatiles from Cling Peaches. *J. Agric. Food Chem.* **1978**, *104*, 626–629.

USDA. Statistics of Fruits, Tree Nuts, and Horticultural Specialities. In *Agricultural Statistics, 1986*; U.S. Government Printing Office: Washington, DC, 1986; Chapter 5, p 211.

Watada, A. E.; Anderson, R. E.; Aulenbach, B. B. Sensory, Compositional, and Volatile Attributes of Controlled Atmosphere Stored Peaches. *J. Am. Soc. Hortic. Sci.* **1979**, *104*, 626–629.

Received for review November 1, 1988. Accepted March 20, 1989. References to brand or firm names do not constitute endorsement by the U.S. Department of Agriculture over others of a similar nature.