Potential Maturity Indices and Developmental Aspects of Melting-flesh and Nonmelting-flesh Peach Genotypes for the Fresh Market

Ernesto A. Brovelli,¹ Jeffrey K. Brecht, and Wayne B. Sherman

Horticultural Sciences Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL 32611-0690

Charles A. Sims

Food Science and Human Nutrition Department, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, Florida 32611-0370

ADDITIONAL INDEX WORDS. fruit growth, firmness, color, texture, *Prunus persica*, ethylene, respiration

ABSTRACT. Potential maturity indices were determined for two melting-flesh (FL 90-20 and 'TropicBeauty') and two nonmelting-flesh ('Oro A' and FL 86-28C) peach [*Prunus persica* (L.) Batsch.] genotypes. A range of developmental stages was obtained by conducting two harvests and separating the fruit based on diameter. Fruit in each category were divided into two groups. One group was used to determine potential maturity indices: soluble solids, titratable acidity, soluble solids to titratable acidity ratio, peel and flesh color on the cheeks and blossom end, cheek and blossom-end firmness, ethylene production, and respiration rate. The other group was stored at 0 °C for 1 week and ripened at 20 °C for 2 days to simulate handling conditions and presented to a trained sensory panel, which rated the fruit for three textural aspects (hardness, rubberiness, and juiciness) and six flavor aspects (sweetness, sourness, bitterness, and green, peachy, and overripe character). Principal component (PC) analysis was used to consolidate the results of the descriptive sensory evaluation into a single variable that could be correlated with the objective measurements at harvest. The attributes that best correlated with the first sensory PC of each genotype, and thus are promising maturity indices, were as follows: for FL 90-20, peel hue, peel L, and cheek firmness; for 'TropicBeauty', peel L, cheek firmness, and blossom-end firmness; for 'Oro A', cheek firmness, blossom-end firmness, and cheek chroma; and for 86-28C, blossom-end firmness, cheek hue, and cheek firmness.

The concept of horticultural maturity implies the use of a measurable character, changes in which can be used to indicate when a commodity should be harvested for a particular purpose. This character is known as a maturity or harvesting index (Reid, 1992). Maturity indices for various horticultural crops have relied on different features of the commodity, such as duration of development, size, density, starch or sugar content, color, and firmness (Shewfelt, 1993).

The search for maturity indices for different peach varieties for the fresh market has been extensive. Methodology for their determination, however, has differed considerably. Several researchers focused on the correlations between different physicochemical attributes of the fruit or on the progression of these attributes with advancing maturity (Delwiche and Baumgardner, 1985; Salunkhe et al., 1968; Sims and Comin, 1963). Alternatively, others considered the relationship between various physicochemical aspects of fruit at harvest and their edible quality. The determining of edible quality, however, was not consistent among researchers. While Delwiche and Baumgardner (1983) and Meredith et al. (1989) measured acceptability by means of sensory panels composed of 5 to 15 judges, Robertson et al. (1992) used descriptive sensory panels but did not assess fruit acceptability.

Parameters that have proved to be reliable indicators of maturity for different cultivars also vary. While fruit size, soluble solids content, and titratable acidity depend on fruit maturity, the influence of other factors such as crop load or climatic conditions limit the reliability of these predictors (Crisosto, 1994). The effective-

ness of flesh firmness as a maturity index was reported by Rood (1957) and Salunkhe et al. (1968). Alternatively, others proposed using ground color to identify horticultural maturity (Delwiche and Baumgardner, 1983, 1985; Luchsinger and Walsh, 1993). New technological tools, such as delayed light emission (Chapman et al., 1991; Forbus and Dull, 1990) and microwave permittivity (Nelson et al., 1994), are emerging as potential means of detecting maturity in peaches. The main purpose of these approaches, however, is to assist in on-line processes such as sorting and grading and not in the harvesting scheme.

An important goal for some current peach breeding programs is to combine the flesh firmness found in nonmelting-flesh (NMF) genotypes commonly used for processing with the ideal fresh-market quality attributes found in melting-flesh (MF) genotypes. The objective is to obtain fruit that can attain maximum flavor on the tree, but that are less prone to mechanical damage and decay associated with excessive softening (Sherman et al., 1990). While maturity indices for many fresh-market MF peach cultivars have been identified, NMF fruit have received less attention. The limited softening nature of NMF fruit poses the question of whether flesh firmness can be used as a maturity index. Additionally, the early development of peel blush in newer cultivars requires research to test the validity of ground color as an effective maturity index.

The decision of when to harvest peaches is a critical one. Overripe fruit are extremely susceptible to injury and decay. Immature fruit may not ripen to standards required by consumers, and, if stored under an inappropriate temperature regime, may be prone to chilling injury. It is therefore critical to determine when a peach has reached horticultural maturity and can reach the consumer in satisfactory condition after having undergone a specified storage and handling period. The objective of this study was to determine potential maturity indices for two NMF genotypes for the fresh market: 'Oro A' and FL 86-28C.

Received for publication 10 June 1997. Accepted for publication 16 Dec. 1997. Florida Agricultural Experiment Station journal series no. R-05812. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

¹Current address: Nutrilite, 19600 6th St., Lakeview, CA 92567-8403.

Materials and Methods

PLANT MATERIAL. The study, which initially concentrated on the NMF genotypes 'Oro A' and FL 86-28C, was started in 1994. In 1995, the MF genotypes FL 90-20 and 'TropicBeauty' were also included to compare the behavior of NMF fruit with that of MF fruit. The source of all genotypes was the Teaching Orchard, Horticultural Sciences Dept., Univ. of Florida, Gainesville. Each NMF genotype was paired with a MF genotype of comparable maturity date. In Florida, FL 90-20 and 'Oro A' are extremely early-season genotypes. The fruit of FL 90-20 are yellow fleshed, have 80% of the skin red blushed, and are ≈ 80 g at maturity. The fruit of 'Oro A' are yellow fleshed, have no red blush, and are ≈ 70 g at maturity. 'TropicBeauty' and FL 86-28C are later-season genotypes. The fruit of 'TropicBeauty' are yellow fleshed, have 80% of the skin red blushed, and are ≈ 120 g at maturity. The fruit of FL 86-28C are yellow fleshed, have 80% of the skin red blushed, and are ≈ 115 g at maturity.

METHODOLOGICAL APPROACH. The basis for determining a maturity index was to conduct a linear correlation between a series of physicochemical attributes measured at harvest and the final sensory assessments of the fruit. The attributes showing the best correlation coefficients are those with the best potential for becoming maturity indices.

Three issues considered in developing the protocol were as follows. 1) Since, in the case of peaches, paired observations (measurements at harvest and the corresponding sensory assessments) for individual fruit are unrealizable due to limitations in fruit size, data points in the correlation result from samples of fruit of a specific class. To strengthen the correlation by increasing the number of data points, a grading scheme that resulted in a large number of fruit classes was implemented. The larger the number of fruit classes, the greater the chance of finding a significant correlation between measurements at harvest and sensory assessments. 2) The determination took into account a storage period that simulated the time that elapses from harvest to consumption in the commercial marketing chain. 3) Results from the descriptive sensory evaluation were consolidated into a single meaningful variable by means of principal component (PC) analysis (Piggott and Sharman, 1986; Resurreccion, 1988). The first sensory principal component (PC1), which explains the highest proportion of the variability, was correlated with the physicochemical attributes measured at harvest.

The results from the 1994 harvest provided preliminary information to determine a maturity index in 1995. In 1994, fruit were harvested on three dates at intervals of 7 d. To determine when to conduct the first harvest for each NMF genotype, fruit diameter, as measured with a fruit gauge (Cranston, Inc., Oak Grove, Ore.), was recorded over time for a sample of 20 labeled fruit on each of three trees. The first harvest was to be conducted when the average fruit growth reached a plateau. Harvesting was selective for those fruit visually representative of the average ground color of a tree load on each harvest day. The fruit collected in each harvest were considered to represent a maturity category. In the last harvest of the NMF genotype FL 86-28C, when ease of detachment (tugging as opposed to yanking the fruit) and visual observation of the stem-end area allowed for a clear distinction between fruit with and without a well-developed abscission zone, fruit were divided into two additional maturity categories based on that feature.

Immediately after the 1994 harvests, the fruit were brought into the laboratory and distributed in the following manner: 15 fruit were set aside to measure physicochemical attributes at harvest (diameter, fresh mass, peel ground color, flesh color and firmness,

pH, soluble solids, and titratable acidity), 9 fruit were assigned to the measurement of ethylene production, and 15 fruit were stored at 0 °C for 14 d and subsequently ripened at 20 °C until the ethylene peak was observed. At this point, these fruit were removed from storage and underwent sensory evaluation.

In 1994, the correlation between attributes at harvest and sensory PC1 was conducted jointly for 'Oro A' and FL 86-28C using measurements at harvest and sensory assessments for both genotypes in combination. In this way, the variability existing for the NMF genotypes was represented more accurately. Since the goal was to have as many fruit categories as possible, based on the results from 1994, it was possible to define which attributes best correlated with the sensory PC1 and, thus, to determine which of them had the best potential as a grading criterion for 1995.

In 1995, fruit were harvested on two dates at intervals of 7 d. While the fruit categories in 1994 were only based on their harvest dates, in 1995 fruit within each harvest were further classified based on their diameter into six classes based on a scale that progressed in 0.16-cm increments. Since FL 90-20, FL 86-28C, and 'TropicBeauty' have fruit innately larger than those of 'Oro A', the initial class was 2.70 to 2.86 cm for the first three genotypes and 2.06 to 2.22 cm for 'Oro A'. Fruit within each class were divided into three lots: 9 fruit for measuring ethylene production and respiration rate, 15 fruit for sensory evaluation after having been stored for 1 week at 0 °C and ripened for 2 d at 20 °C, and 15 fruit for measuring physicochemical attributes at harvest. These physicochemical measurements at harvest were the same as in 1994, except for fresh mass, which was excluded, and the initial respiration rate, which was added to the list. In 1995, all measurements and evaluations were conducted alike for MF and NMF fruit.

COLOR DETERMINATION. L^* , a^* , and b^* values were determined using a Minolta CR-200 reflectance colorimeter under D_{65} illuminant conditions. Results were expressed as L^* value, hue angle (arc tangent of b^*/a^*), and chroma ($(a^{*2} + b^{*2})^{1/2}$) (McGuire, 1992). Ground color was measured on the greenest (or least orange, in more advanced stages) portion of the peel. Flesh color in the cheeks was measured on a flat surface obtained by removing epicarp and mesocarp tissue from both sides of the fruit by slicing parallel to the suture at the equator to a depth of ≈ 0.5 cm into the flesh. Measurements were taken at both cheeks and results were averaged. Blossom-end flesh color was measured at ≈ 0.5 cm into the flesh at the blossom end.

FIRMNESS DETERMINATION. Flesh firmness was measured with an Instron (model 1132), which applied compressive force from a 500-kg load cell. A convex-tip probe (Magness-Taylor type), 1.1 cm in diameter, was attached to the load cell moving at a speed of 10 cm·min⁻¹. Firmness was evaluated on the same flat surfaces (cheeks and blossom ends) where color was measured.

COMPOSITIONAL ANALYSIS. To measure soluble solids, pH, and titratable acidity, fruit were peeled, sliced, pitted, and pureed in a Waring blender for 1 min. The slurry was centrifuged (20 min; 17,600 g ; 6 °C) and the fluid fraction was used to determine soluble solids by refractometry, titratable acidity by titration with 0.1 NaOH, and pH.

ETHYLENE PRODUCTION AND RESPIRATION RATE DETERMINATION. Ethylene production and respiration rate were measured after storing the fruit at 20 °C for 24 h following harvest. Ethylene production and respiration rate were measured on three replications of three fruit each, which were sealed for 1 h in 1.75-L glass jars. For headspace sampling, syringes were inserted through rubber septa affixed on the lid. Samples for ethylene determination were analyzed using a gas chromatograph equipped with an activated alumina-packed column and a photoionization detector. Samples for determining CO₂ were analyzed using a gas chromato-

graph equipped with a Cumpack-packed column and a thermal conductivity detector.

SENSORY EVALUATION. Fruit were peeled and sliced into ≈ 1 -cm wide wedges, which were mixed in a bowl and presented in duplicate to four female and six male panelists (graduate students and faculty of the Food Science and Human Nutrition Dept.), ranging in age from 25 to 48. Evaluations were conducted at 10 AM in private booths, where distilled water and unsalted crackers were provided. Assessments were recorded on a descriptive 15-point scale, with 1 = low and 15 = high as anchors. Panelists were trained in several sessions, during which they became familiar with the different varieties and stages of maturity. After being allowed to work independently, they were taken to consensus by a project leader on which notes were needed to define the differences between the samples and the range in which these notes were expected to fluctuate. Two types of aspects were assessed: textural notes (hardness, rubberiness, and juiciness) and flavor notes (sweetness, sourness, bitterness, and green, peachy, and overripe character).

STATISTICAL DESIGN. Data from the physicochemical determinations conducted in 1994 were analyzed according to a completely randomized design, with harvest date as a fixed effect. Results from the 1995 physicochemical determinations were analyzed according to a nested design, with fixed diameter class effects nested within fixed genotype effects. Means were separated by pairwise *t* tests with a Bonferroni correction (Hsu, 1996).

Results and Discussion

THE 1994 STUDY. Based on ground color and firmness, fruit of 'Oro A' and FL 86-28C appeared to reach maturity before the

growth of the tagged fruit had stabilized. Therefore, the plan to conduct the first harvest once growth had reached a plateau had to be modified. 'Oro A' fruit increased in diameter and mass between the first and second harvest, while FL 86-28C fruit increased through all three harvests (data not shown). This suggests that these NMF genotypes reached horticultural maturity before full size was attained. Others have reported that peaches will not ripen properly if they are harvested before they have ceased growing (Connors, 1919; Delwiche and Baumgardner, 1983), but we saw no evidence of this in 'Oro A' or FL 86-28C.

While there was little (FL 86-28C) or no ('Oro A') change in the soluble solids content observed during maturation, significant increases in pH and soluble solids to titratable acidity ratio and decreases in titratable acidity occurred in both genotypes (data not shown). The behavior with regard to soluble solids content may result from a genetic predisposition observed in other clingstone peach genotypes (Brooks et al., 1993; Robertson et al., 1993). In FL 86-28C, significant differences between fruit with and without development of an abscission zone were observed for all physicochemical aspects except the soluble solids content, with fruit with a developed abscission zone being larger and having higher pH, lower titratable acidity, and higher soluble solids to titratable acidity ratio (data not shown). Significant decreases in ground, cheek and blossom-end L^* value and hue, as well as cheek firmness, were observed in both NMF genotypes (data not shown). In FL 86-28C, the cheek firmness of fruit with a developed abscission zone was remarkably less than that of fruit without development of an abscission zone (data not shown).

The production of ethylene 24 h after harvest increased with maturation in both NMF genotypes (data not shown). A similar observation was reported by Miller et al. (1988), who noted that

Table 1. Physicochemical attributes of 'Oro A' [nonmelting flesh (NMF)] and FL 90-20 [melting flesh (MF)] at harvest (1995).

Genotype	Harvest	Diam class	pH	Soluble solids (SS) ($^{\circ}$ Brix)	Titratable acidity (TA) (% malic)	SS:TA
Oro A (NMF)	1	1	3.79 cd ²	9.55 b	2.23 a	4.53 c
		2	3.81 bcd	10.07 b	2.03 ab	4.70 bc
		3	3.88 abcd	10.57 b	1.82 abc	6.11 bc
		4	4.04 a	10.32 b	1.68 abc	6.60 abc
		5	3.91 abcd	16.07 a	1.40 bc	11.67 a
		6	3.94 abcd	12.52 ab	1.26 c	10.11 abc
	2	1	3.76 d	10.12 b	1.68 abc	6.10 bc
		2	3.99 abcd	11.32 ab	1.30 c	8.82 abc
		3	3.92 abcd	10.37 b	1.42 bc	7.88 abc
		4	4.04 ab	10.22 b	1.31 c	7.92 abc
		5	3.93 abcd	12.72 ab	1.29 c	10.11 ab
		6	4.00 abc	11.47 ab	1.34 bc	8.61 abc
FL 90-20 (MF)	1	1	3.64 b	9.77 a	1.43 abc	6.74 b
		2	3.64 b	7.27 a	1.61 ba	4.45 b
		3	3.61 b	10.1 a	1.97 a	5.24 b
		4	3.71 b	9.80 a	1.70 ab	5.77 b
		5	3.74 b	10.55 a	1.65 ab	6.44 b
		6	3.63 b	10.20 a	1.59 ab	6.41 b
	2	1	NA ³	NA	NA	NA
		2	4.02 ab	10.77 a	1.25 bcd	9.25 ab
		3	3.93 ab	9.37 a	0.90 cde	10.58 ab
		4	4.28 a	10.07 a	0.68 e	15.11 a
		5	4.21 a	10.67 a	0.75 ed	14.77 a
		6	NA	NA	NA	NA

²Means within columns for each genotype were separated by pairwise *t* tests with Bonferroni correction at experimentwise $\alpha = 0.05$.

³NA = not available—an insufficient quantity of fruit of that particular class was available for analysis.

Table 2. Physicochemical attributes of FL 86-28C [nonmelting flesh (MF)] and 'TropicBeauty' [melting flesh (MF)] at harvest (1995).

Genotype	Harvest	Diam class	pH	Soluble solids (SS) (°Brix)	Titrateable acidity (TA) (% malic)	SS:TA
FL 86-28C (NMF)	1	1	3.60 c ^z	9.2 ab	1.72 a	5.36 c
		2	3.69 c	7.9 b	1.29 ab	6.46 c
		3	3.87 abc	9.4 ab	1.12 b	8.68 bc
		4	3.90 abc	10.2 ab	1.07 b	9.83 abc
		5	3.77 bc	9.8 ab	1.27 ab	8.02 bc
		6	4.13 ab	10.5 ab	0.79 b	13.30 ab
	2	1	3.86 abc	10.8 ab	0.95 b	11.81 abc
		2	3.84 abc	11.1 ab	1.18 ab	10.16 abc
		3	3.89 abc	11.4 ab	1.02 b	11.28 abc
		4	3.89 abc	11.6 a	1.03 b	11.42 abc
		5	3.90 abc	11.2 ab	1.17 ab	9.72 abc
		6	4.21 a	11.9 a	0.77 b	16.03 a
TropicBeauty (MF)	1	1	NA ^y	NA	NA	NA
		2	3.61 bc	8.42 b	2.36 a	3.58 c
		3	3.63 bc	11.30 ab	2.19 ab	5.16 bc
		4	3.60 c	11.52 ab	2.17 ab	5.33 bc
		5	3.58 c	10.95 ab	2.00 abc	5.45 bc
		6	3.80 a	12.40 a	1.44 d	8.67 a
	2	1	NA	NA	NA	NA
		2	3.77 a	8.52 b	1.77 bcd	4.89 bc
		3	3.72 bc	12.30 a	1.71 dc	7.24 ab
		4	3.75 ab	12.20 a	1.77 bcd	6.88 ab
		5	NA	NA	NA	NA
		6	3.86 a	12.95 a	1.50 d	8.86 a

^zMeans within columns for each genotype were separated by pairwise *t* tests with Bonferroni correction at experimentwise $\alpha = 0.05$.^yNA = not available—an insufficient quantity of fruit of that particular class was available for analysis.

monitoring the increase in ethylene production in peach fruit might have some potential as a maturity index. Unlike most of the physicochemical attributes, the development of the abscission zone in fruit of FL 86-28C did not affect the levels of ethylene production (data not shown).

The linear correlation between the fruit attributes at harvest and sensory PC1 revealed which fruit attributes best correlated with the

final assessment of edible quality for 1994. Following are the five attributes with the highest correlation coefficients, all of which were highly significant ($P < 0.01$): blossom-end hue (−0.96), blossom-end firmness (−0.95), diameter (0.90), titrateable acidity (−0.83), and soluble solids to titrateable acidity ratio (0.80). The identification of these five attributes was critical in defining a parameter that allowed for the separation of fruit into multiple

Table 3. Respiration (CO₂) and C₂H₄ production rates measured 24 h after harvest (1995) for nonmelting flesh (NMF) and melting flesh (MF) peach genotypes.

Harvest	Grade	Genotype							
		Oro A (NMF)		FL 90-20 (MF)		FL 86-28C (NMF)		TropicBeauty (MF)	
		C ₂ H ₄ production (μL·kg ^{−1} ·h ^{−1})	Respiration rate (mL·kg ^{−1} ·h ^{−1})	C ₂ H ₄ production (μL·kg ^{−1} ·h ^{−1})	Respiration rate (mL·kg ^{−1} ·h ^{−1})	C ₂ H ₄ production (μL·kg ^{−1} ·h ^{−1})	Respiration rate (mL·kg ^{−1} ·h ^{−1})	C ₂ H ₄ production (μL·kg ^{−1} ·h ^{−1})	Respiration rate (mL·kg ^{−1} ·h ^{−1})
1	1	4.10 d ^z	35.15 a	1.07 d	32.71 a	20.91 b	43.45 b	NA ^y	NA
	2	44.93 abc	49.78 a	2.72 abcd	35.25 a	35.17 ab	45.55 b	1.80 c	30.46 ab
	3	55.62 a	51.75 a	1.96 bcd	36.82 a	36.87 ab	49.11 b	1.65 c	24.26 b
	4	48.94 ab	41.55 a	4.15 abcd	31.18 a	41.47 ab	47.15 b	4.86 b	30.81 ab
	5	40.58 abc	43.08 a	2.26 abcd	34.00 a	33.62 ab	36.21 b	4.31 b	31.16 ab
	6	38.67 abc	55.27 a	3.18 abcd	33.67 a	49.69 a	36.65 b	9.87 a	36.26 a
2	1	18.62 cd	14.27 b	1.56 cd	34.93 a	16.49 b	22.10 b	NA	NA
	2	25.61 bcd	55.07 a	3.09 abcd	42.12 a	43.25 a	66.55 a	NA	NA
	3	54.48 a	47.57 a	2.18 abcd	32.23 a	34.66 ab	28.86 b	NA	NA
	4	44.36 abc	48.57 a	4.49 ab	26.62 a	25.15 b	32.53 b	NA	NA
	5	36.95 abc	55.68 a	4.17 abc	38.10 a	35.28 ab	22.32 b	NA	NA
	6	53.87 a	49.54 a	4.87 a	29.72 a	NA	NA	NA	NA

^zMeans within columns for each genotype were separated by pairwise *t* tests with Bonferroni correction at experimentwise $\alpha = 0.05$.^yNA = not available—an insufficient quantity of fruit of that particular class was available for analysis.

Table 4. Ground, cheek flesh, and blossom-end flesh color of 'Oro A' [nonmelting flesh (NMF)] and FL 90-20 [melting flesh (MF)] at harvest (1995).

Genotype	Harvest	Grade	Ground color			Cheek flesh color			Blossom-end flesh color		
			L*	Hue	Chroma	L*	Hue	Chroma	L*	Hue	Chroma
Oro A	1	1	66.1 bc ^z	97.5 a	51.0 d	69.8 ab	92.2 a	57.1 a	70.1 a	91.1 a	63.8 a
		2	65.5 c	96.0 a	51.1 d	70.6 ab	90.3 ab	56.2 abc	70.5 a	87.4 ab	65.7 a
		3	65.8 abc	89.9 b	52.7 cd	69.4 b	87.1 ab	54.3 abcd	70.4 a	85.0 ab	64.6 a
		4	66.3 abc	89.4 b	53.8 cd	71.1 ab	87.1 ab	52.1 bcde	70.4 a	84.3 ab	64.9 a
		5	67.0 abc	86.0 bc	54.4 bc	70.3 ab	85.8 ab	53.5 abcde	69.9 a	83.4 ab	61.0 a
		6	67.6 abc	83.7 cd	54.6 abc	69.8 ab	85.4 ab	50.4 de	71.8 a	84.7 ab	53.9 b
	2	1	66.1 bc	89.4 b	54.0 cd	69.1 b	86.4 ab	56.7 ab	70.8 a	84.6 ab	64.6 a
		2	67.9 ab	82.0 cd	57.8 a	70.1 ab	83.9 bc	50.7 de	70.6 a	80.4 bc	64.9 a
		3	67.6 bc	85.5 bcd	55.8 abc	70.9 ab	86.2 ab	52.4 abcde	70.8 a	81.4 bc	63.3 a
		4	68.6 a	82.7 cd	57.7 a	71.7 a	84.8 ab	49.6 de	71.1 a	82.0 bc	63.3 a
		5	67.2 abc	81.6 cd	57.2 ab	70.2 ab	76.0 c	51.6 cde	69.0 a	74.4 c	60.4 ab
		6	67.6 abc	80.9 d	57.6 a	70.7 ab	84.4 ab	49.0 e	70.4 a	81.9 bc	59.3 ab
FL 90-20 (MF)	1	1	67.3 a	76.7 a	49.2 a	69.2 b	81.1 b	48.4 c	73.4 a	85.7 a	55.4 a
		2	61.8 abc	65.5 ab	44.6 b	75.4 a	91.7 a	53.9 abc	71.1 ab	76.4 ab	61.6 a
		3	62.1 abc	64.4 abc	44.6 b	76.6 a	91.1 a	55.5 ab	69.0 ab	74.5 a	56.2 a
		4	64.0 ab	68.2 ab	46.3 ab	73.8 ab	88.5 a	57.0 a	72.3 ab	79.9 ab	56.8 a
		5	62.4 abc	66.8 ab	45.8 ab	75.3 a	89.2 a	58.0 a	68.5 ab	76.2 ab	57.4 a
		6	58.0 bc	56.3 bc	47.6 ab	74.3 ab	84.9 ab	55.2 ab	67.7 ab	74.4 b	56.3 a
	2	1	59.7 abc	65.0 abc	45.9 ab	73.7 ab	87.1 ab	57.8 a	72.5 ab	81.0 ab	60.5 a
		2	57.5 bc	57.5 bc	44.4 b	74.0 ab	87.7 ab	56.6 a	72.5 ab	81.2 ab	58.1 a
		3	59.1 abc	57.7 bc	46.0 ab	73.2 ab	85.5 ab	56.0 a	73.7 a	86.2 ab	56.8 a
		4	58.6 abc	61.9 abc	46.1 ab	72.4 ab	87.1 ab	54.3 ab	72.9 ab	83.8 ab	62.2 a
		5	58.6 abc	59.1 abc	48.1 ab	72.9 ab	86.8 ab	55.1 ab	73.1 ab	83.7 ab	59.6 a
		6	53.6 c	47.2 c	47.3 ab	71.9 ab	85.2 ab	50.1 bc	72.6 b	80.1 ab	55.3 a

^zMeans within columns for each genotype were separated by pairwise *t* tests with Bonferroni correction at experimentwise $\alpha = 0.05$.

Table 5. Ground, cheek flesh, and blossom-end flesh color of FL 86-28C [nonmelting flesh (NMF)] and TropicBeauty' [melting flesh (MF)] at harvest (1995).

Genotype	Harvest	Grade	Ground color			Cheek flesh color			Blossom-end flesh color		
			L*	Hue	Chroma	L*	Hue	Chroma	L*	Hue	Chroma
FL 86-28C (NMF)	1	1	68.8 a ^z	86.6 a	50.6 b	74.2 a	93.3 a	59.1 abc	74.0 a	88.8 a	65.1 a
		2	65.0 ab	70.9 b	53.9 ab	73.4 ab	86.4 b	60.3 abc	71.5 a	80.1 b	66.2 a
		3	63.3 abc	67.3 bc	54.8 ab	71.9 abc	83.8 cb	59.4 abc	71.0 a	77.6 bc	63.2 a
		4	61.8 bc	61.8 bc	57.3 a	72.5 abc	82.4 cb	59.5 abc	71.6 a	76.9 bc	64.4 a
		5	61.4 bc	61.8 bc	54.2 ab	72.0 abc	81.8 bc	59.9 abc	71.2 a	77.0 bc	64.0 a
		6	64.4 ab	62.7 bc	57.5 a	71.6 abc	79.4 cd	55.8 c	69.8 a	72.8 cd	61.0 a
	2	1	62.7 abc	62.6 bc	55.9 a	70.8 bc	83.0 bc	63.5 a	69.4 a	76.6 bcd	63.6 a
		2	61.8 bc	64.3 bc	54.4 ab	70.7 bc	83.3 bc	61.7 ab	69.7 a	77.8 bc	64.8 a
		3	61.8 bc	61.3 bc	56.6 a	71.2 abc	81.9 bc	62.9 a	69.3 a	76.0 bcd	65.7 a
		4	62.3 bc	63.3 bc	56.9 a	70.7 bc	82.3 bc	57.4 bc	68.9 a	77.1 bc	63.4 a
		5	59.4 bc	57.5 c	55.1 ab	69.8 cd	80.9 bcd	60.8 ab	68.4 a	76.3 bc	66.5 a
		6	57.9 c	57.3 c	56.9 a	67.1 d	76.0 d	57.1 bc	90.4 a	70.1 d	64.4 a
TropicBeauty (MF)	1	1	NA ^y	NA	NA	NA	NA	NA	NA	NA	NA
		2	68.3 a	83.5 a	48.8 a	78.0 a	90.2 a	55.7 ab	74.2 a	85.9 a	62.8 a
		3	65.8 a	72.5 ab	49.8 a	75.8 ab	85.6 ab	54.2 ab	72.4 ab	81.3 ab	62.7 a
		4	64.2 ab	66.7 bc	49.4 a	75.8 ab	85.0 ab	56.0 ab	73.0 a	81.5 ab	63.9 a
		5	64.7 ab	67.5 bc	50.1 a	75.6 ab	84.3 abcd	54.6 ab	69.6 abc	76.5 abc	61.4 a
		6	61.8 abc	64.6 bc	50.7 a	62.7 d	73.5 e	51.2 b	61.5 e	66.6 c	58.6 a
	2	1	NA	NA	NA	NA	NA	NA	NA	NA	NA
		2	63.1 abc	66.5 bc	48.1 a	70.1 bc	79.3 bcde	57.6 a	66.6 bcde	73.4 bc	61.6 a
		3	61.6 abc	62.0 bc	50.4 a	68.4 cd	78.1 cde	57.8 a	68.1 abcd	76.6 abc	64.4 a
		4	58.2 bc	56.5 c	49.0 a	67.4 cd	77.2 de	56.8 ab	62.2 de	68.7 c	60.6 a
		5	NA	NA	NA	NA	NA	NA	NA	NA	NA
		6	57.7 c	57.0 c	49.7 a	64.9 cd	78.2 cde	52.5 ab	66.0 cde	75.9 abc	59.2 a

^zMeans within columns for each genotype were separated by pairwise *t* tests with Bonferroni correction at experimentwise $\alpha = 0.05$.^yNA = not available—an insufficient quantity of fruit of that particular class was available for analysis.

Table 6. Cheek and blossom-end firmness (N) at harvest (1995) for nonmelting flesh (NMF) and melting flesh (MF) peach genotypes.

Harvest	Grade	Genotype							
		Oro A (NMF)		FL 90-20 (MF)		FL 86-28C (NMF)		TropicBeauty (MF)	
		Cheek	Blossom end	Cheek	Blossom end	Cheek	Blossom end	Cheek	Blossom end
1	1	65 a ^z	114 a	71 a	77 a	92 a	127 a	NA ^y	NA
	2	55 b	71 ab	65 a	58 abc	76 a	94 b	80 a	107 a
	3	40 cd	55 b	66 a	68 ab	56 b	65 cd	63 ab	76 b
	4	36 def	45 b	53 ab	41 abc	42 bcd	61 cd	57 ab	65 b
	5	36 def	44 b	58 ab	47 abc	43 bcd	58 cd	50 b	52 bc
	6	29 ef	36 b	48 abc	37 abc	36 de	53 cd	48 b	50 bc
2	1	48 bc	64 b	52 ab	74 ab	50 bcd	65 cd	NA	NA
	2	33 def	47 b	49 abc	64 abc	53 bc	74 bc	40 bc	49 bcd
	3	37 de	49 b	38 bcd	67 ab	47 bcd	67 cd	24 c	26 cde
	4	31 ef	42 b	27 cd	42 abc	37 cde	58 cd	20 cd	19 de
	5	31 ef	43 b	25 cd	31 bc	38 cde	61 cd	NA	NA
	6	28 f	38 b	15 d	21 c	24 e	47 d	5 d	5 e

^zMeans within columns for each genotype were separated by pairwise *t* tests with Bonferroni correction at experimentwise $\alpha = 0.05$.

^yNA = not available—an insufficient quantity of fruit of that particular class was available for analysis.

categories for the 1995 harvests. Fruit diameter was selected as the best grading criterion as it was nondestructive and easy to implement. The potential of diameter as a maturity index, however, is questionable as it can be affected by factors such as crop load and rainfall.

THE 1995 STUDY. Developmental aspects of the fruit in 1995 reflect changes associated with harvest date as well as fruit diameter. In all four genotypes, increases in pH and the soluble solids to titratable acidity ratio and decreases in titratable acidity were observed between fruit of the smallest diameter in harvest one (H1-D1) and those of the largest diameter in harvest two (H2-D6) (Tables 1 and 2).

Neither the ethylene production rate nor the respiration rate measured 24 h after harvest was markedly affected by harvest date or fruit diameter (Table 3).

Ground color and flesh hue angles decreased with later harvests and increasing fruit diameter in all four cultivars. This trend reflects the increase in red and orange pigmentation occurring during maturation. As in 1994, hue angle measurements of the cheek flesh were consistently higher than those at the blossom end, thus indicating a higher proportion of red and orange components in the blossom-end region of the fruit (Tables 4 and 5).

Significant decreases in cheek and blossom-end firmness were detected in all four genotypes with increasing diameter and later harvests (Table 6). This indicates that the softening of the flesh that occurs during the maturation of MF genotypes (Meredith et al., 1989; Robertson et al., 1992) can also be expected in NMF fruit. However, the observed drop in firmness was much greater in the MF genotypes than in their NMF counterparts. According to Lester et al. (1996), MF and NMF fruit show an initial loss of firmness during maturation, but NMF fruit lack the final melting

phase of softening. As in 1994, firmness at the blossom end was generally higher than at the cheek region of the fruit.

In 1995, individual linear correlations were conducted between each genotype's fruit attributes at harvest and their respective sensory PC1 values. Table 7 shows the attributes with the highest correlation coefficients and their statistical significance. For each genotype, the attributes with the highest potential of becoming maturity indices are as follows: for Oro A (NMF), cheek firmness; for FL 90-20 (MF), hue; for FL 86-28C (NMF), blossom-end firmness; and for TropicBeauty (MF), L*. It is apparent that each genotype has different attributes that best correlate with their respective sensory PC1. However, two attributes—blossom-end firmness and cheek firmness—were highly correlated with sensory PC1s in all four genotypes. This demonstrates the importance of firmness as a potential maturity index, even in NMF genotypes, where decreases in flesh firmness with maturation are not as striking as in MF types. The skin's ground color, which is often considered the most accurate predictor of fruit maturity (Crisosto, 1994), was more meaningful for MF than for NMF genotypes. Unlike firmness and color, compositional attributes and ethylene production had lesser potentials as maturity indices.

The average percentage of the variation explained by PC1 is 60%. The factor loadings reported in Table 8 represent the relative importance that each sensory note has in the definition of each PC. Based on the similar weight of the factor loadings for each genotype's PC1, it can be inferred that the attributes shown in Table 8 not only provide an indication of the fruit's final quality assessment as determined by PC1, but are also a fair reflection of most of the individual sensory notes.

To define specific maturity indices and their thresholds for each genotype, it is critical to repeat this work over many growing

Table 7. Attributes² and their corresponding correlation coefficients with PC1 (1995).

Oro A (NMF)	FL 90-20 (MF)	FL 86-28C (NMF)	TropicBeauty (MF)
CH firmness (−0.85**)	GC hue (−0.88**)	BE firmness (−0.91**)	GC L* (−0.84**)
BE firmness (−0.82**)	GC L* (−0.85**)	CH hue (−0.90**)	CH firmness (−0.83**)
CH chroma (−0.82**)	CH firmness (−0.81**)	CH firmness (−0.90**)	BE firmness (−0.79**)
SS:TA (0.80**)	BE firmness (−0.75**)	BE hue (−0.87**)	GC hue (−0.70**)
TA (−0.77*)	SS:TA (−0.52 ^{NS})	C ₂ H ₄ production (0.80*)	pH (0.65**)

²NMF = nonmelting flesh, MF = melting flesh, GC = ground color, CH = cheek, BE = blossom end, SS = soluble solids, TA = titratable acidity.

^{NS},*,** Nonsignificant or significant at $\alpha = 0.05$ or 0.01, respectively.

Table 8. Factor loadings for first sensory principal components (1995) for nonmelting flesh (NMF) and melting flesh (MF) peach genotypes.

Note	Oro A (NMF)	FL 90-20 (MF)	FL 86-28C (NMF)	Tropic Beauty (MF)
Hardness	0.391	0.418	-0.396	0.412
Juiciness	0.448	0.448	0.466	0.447
Rubberiness	-0.278	0.085	-0.243	0.328
Sweetness	0.422	0.417	0.400	0.395
Sourness	0.349	0.371	0.380	0.365
Bitterness	0.026	0.042	-0.035	0.166
Green character	0.375	0.386	0.353	0.286
Peach character	0.322	0.311	0.253	0.115
Overripe	-0.145	-0.236	-0.263	-0.329

seasons. This study not only provides a methodological framework, but has also narrowed the list of possible maturity indices for each genotype.

Literature Cited

- Brooks, S.J., J.N. Moore, and J.B. Murphy. 1993. Quantitative and qualitative changes in sugar content of peach genotypes [*Prunus persica* (L.) Batsch.]. *J. Amer. Soc. Hort. Sci.* 118:97-100.
- Chapman, Jr., G.W., J.R. Horvat, and W.R. Forbus, Jr. 1991. Physical and chemical changes during the maturation of peaches (cv. Majestic). *J. Agr. Food Chem.* 39:867-870.
- Connors, C.H. 1919. Measurements of peach. *N.J. Agr. Expt. Stat. Annu. Rpt.* 40:82-88.
- Crisosto, C.H. 1994. Stone fruit maturity indices: A descriptive review. *Postharvest News Info.* 5:65N-68N.
- Delwiche, M.J. and R.A. Baumgardner. 1983. Color measurements of peach. *J. Amer. Soc. Hort. Sci.* 108:1012-1016.
- Delwiche, M.J. and R.A. Baumgardner. 1985. Ground color as a peach maturity index. *J. Amer. Soc. Hort. Sci.* 110:53-57.
- Forbus, Jr., W.R. and G.G. Dull. 1990. Delayed light emission as an indicator of peach maturity. *J. Food Sci.* 55:1581-1584.
- Hsu, J.C. 1996. Multiple comparisons. Theory and methods. Chapman and Hall, London.
- Lester, D.R., W.B. Sherman, and B.A. Atwell. 1996. Endopolygalacturonase and the melting flesh (M) locus in peach. *J. Amer. Soc. Hort. Sci.* 121:231-235.
- Luchsinger, L.E. and C.S. Walsh. 1993. Changes in ethylene rate and ground color in peaches (cv. Red Haven and Marqueen) and nectarines (cv. Fantasia) during maturation and ripening. *Acta Hort.* 343:70-72.
- McGuire, R.G. 1992. Reporting of objective color measurements. *HortScience* 27:1251-1255.
- Meredith, F.I., J.A. Robertson, and R.J. Horvat. 1989. Changes in physical and chemical parameters associated with quality and postharvest ripening of Harvester peaches. *J. Agr. Food. Chem.* 37:1210-1214.
- Miller, A.N., B.A. Krizek, and C.S. Walsh. 1988. Whole-fruit ethylene evolution and ACC content of peach pericarp and seeds during development. *J. Amer. Soc. Hort. Sci.* 113:119-124.
- Nelson, S.O., W.R. Forbus, Jr., and K.C. Lawrence. 1994. Assessment of microwave permittivity for sensing peach maturity. *Amer. Soc. Agr. Eng. Paper No.* 96023.
- Piggott, J.R. and K. Sharman. 1986. Methods to aid interpretation of multidimensional data, p. 181-232. In: J.R. Piggott (ed.). *Statistical procedures in food research*. Elsevier, Essex.
- Reid, M.S. 1992. Maturation and maturity indices, p. 21-30. In: A.A. Kader (ed.). *Postharvest technology of horticultural crops*. Univ. of California, Oakland.
- Resurreccion, A.V.A. 1988. Application of multivariate methods in food quality evaluation. *Food Technol.* 42:128-134.
- Robertson, J.A., F.I. Meredith, W.R. Forbus, and B.G. Lyon. 1992. Relationship of quality characteristics of peaches (cv. Loring) to maturity. *J. Food Sci.* 57:1401-1404.
- Robertson, J.A., F.I. Meredith, B.G. Lyon, and G.W. Chapman. 1993. Comparison of quality characteristics of three nonmelting clingstone peach selections. *J. Food Qual.* 16:197-207.
- Rood, P. 1957. Development and evaluation of objective maturity indices for California freestone peaches. *Proc. Amer. Soc. Hort. Sci.* 70:101-112.
- Salunkhe, D.K., P.B. Deshpande, and J.Y. Do. 1968. Effects of maturity and storage on physical and biochemical changes in peach and apricot fruit. *J. Hort. Sci.* 43:235-242.
- Sherman, W.B., B.L. Topp, and P.M. Lyrene. 1990. Nonmelting flesh for fresh market peaches. *Proc. Fla. State Hort. Soc.* 103:293-294.
- Shewfelt, R.L. 1993. Measuring quality and maturity, p. 99-123. In: R.L. Shewfelt and G. L. Staby (eds.). *Postharvest handling: A systems approach*. Academic, San Diego.
- Sims, E.T. and D. Comin. 1963. Evaluation of objective maturity indices for Halehaven peaches. *Proc. Amer. Soc. Hort. Sci.* 82:125-130.