Table 2. Avocado production in selected countries and the world over a 35-year period.

Country	1961 (mt)	1976 (mt)	1996 (mt)
Argentina	2,000	9,050	3,500
Australia	400	570	16,400
Brazil	82,500	139,700	93,800
China	—	—	25,000
Cameroon	12,000	20,000	45,000
Colombia	12,000	15,400	74,000
Costa Rica	10,600	25,500	24,000
Cuba	35,000	10,000	7,500
Dominica	100	100	400
Dominican Republic	106,200	131,500	155,000
Ecuador	16,000	30,600	31,700
Ghana	4,000	4,000	6,300
Guyana	300	410	330
Haiti	40,000	55,000	45,000
Honduras	3,600	4,800	800
Israel	800	18,500	75,900
Jamaica	2,900	2,600	4,000
New Zealand	—	30	2,500
Panama	5,100	2,000	2,800
Philippines	13,300	24,000	26,000
Puerto Rico	4,800	4,000	2,100
St. Lucia	310	390	490
Senegal	—	—	20,000
Seychelles	6	9	15
Spain	340	300	52,100
Trinidad	180	180	310
Venezuela	53,700	40,600	36,300
World total	696,900	1,268,900	2,231,500

Source: FAOSTAT Database, Food & Agricultural Organization, Rome.

cultivars that developed in Florida during the first third of the 20th century, both those of West Indian and of Guatemalan-West Indian hybrid origin, provided high-quality material that permitted development of commercial industries in tropical and subtropical parts of the world with warm-lowland climates similar to that of southern Florida, such as Cameroon, Senegal, the Philippines and Jamaica. The result of this cooperative effort has been a dramatic increase of avocado production in the world as a whole, from 696,000 mt in 1961 to 2,231,500 mt in 1996 (FAOSTAT Database, 1999). This 3.2-fold increase was achieved in large part through the transfer of improved germplasm through two North American conduits: from Mexico through California to the parts of the world where Mediterranean-type climates predominate; and from the Caribbean and Guatemala through Florida to those areas which are characterized by warm, lowland-type climates.

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A PEER REVIEWED PAPER

POSTHARVEST CHARACTERISTICS OF MODERATE-CHILL PEACH VARIETIES

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Abstract. **The postharvest behavior of selected moderate-chill peach [*Prunus persica (L.) Batsch*] varieties was studied over 3 seasons. 'Flordaking' and 'June Gold', currently the dominant cultivars utilized in the South Georgia and North Florida industries, were utilized as standards. Promising alternative varieties were also tested, including 'Flordacrest', 'Texstar', 'White Robin', 'Juneprince' and 'Delta' (a non-melting flesh type). Storage protocol was designed to approximate conditions likely to be encountered during shipment to market via refrigerated truck and subsequent retail marketing, i.e., 5 days at 4°C followed by 2 days at 20°C. Individual fruit weight, fruit firmness (measured as coefficient of restitution) and yellow ground color were measured following the 7-day protocol. Most varieties retained acceptable firmness during the simulated shipping/marketing period. However, non-melting flesh types, such as 'Delta', softened markedly less than melting flesh types, such as 'Flordaking' and 'June Gold'. Both 'Flordaking' and 'June Gold' displayed a high percentage of split pits during this study.**

The goal of the 3-way cooperative project between the USDA, University of Georgia and University of Florida is to develop improved fresh-market peach cultivars for use in the moderate-chill area of the lower coastal plain of the southeastern U.S. This production zone is potentially enormous, stretching along the south Atlantic coast across north Florida and around the entire gulf coast into Texas. However, the industry is currently quite modest in size and is concentrated mostly in South Carolina and Georgia. In part, this is due to the unique climatic requirements this geographical area imposes on cultivars in order to maintain reliable production and still fill early season market windows. Unfortunately, well-adapted cultivars have been low in number because this industry has had to rely on 'spin-offs' from other breeding programs located in and breeding for markedly different environments. This 3-way cooperative program is the first to specifically target the needs of the southeastern coastal plain production area (Beckman et al., 1995).

Early season peaches suffer from a less than shining reputation among consumers. Chief among consumer complaints has been low and inconsistent fruit quality (hard immature fruit, else mushy or mealy texture, split pits) and flavor (sour else bland, lacking aroma). Very few breeding programs objectively evaluate postharvest quality and performance of their breeding materials, instead relying primarily on subjective field evaluations at a relatively immature 'shipping ripe' stage. At this stage of maturity, ground color has begun to change, but flavor (taste and aroma) development is incomplete and not representative of that which the fruit will attain after picking/shipping or if left on the tree. The purpose of this work was (1) to establish objective baseline data for the postharvest performance of standard, moderate-chill peach cultivars, and (2) to compare recent selections from our breeding program with standard varieties in order to gauge their strengths and weaknesses.

Materials and Methods

'Flordaking' and 'June Gold' are the dominant commercial cultivars utilized in the moderate-chill production area of the southeastern coastal plain. Hence, they were utilized as standards. 'Flordacrest', 'Texstar', 'White Robin' (recently released, tested as FL5-16W), 'Juneprince' and 'Delta' are relative newcomers and merit evaluation as alternatives or as possible expansions of this industry's early season market window. With the exception of 'Delta', field performance of these commercially available varieties has been reported (Beckman et al., 1995). 'Delta' is described in Johnson et al., 1994. 'Delta' is unique in that it is a non-melting flesh peach. This type typically softens very slowly during the ripening process. Non-melting flesh germplasm has traditionally been utilized only for the development of canning type peaches where this trait provides significantly stronger flesh integrity during the canning process. In contrast, the flesh of a melting type peach usually falls apart during processing. Early 'SG' (South Georgia) selections out of the cooperative USDA-University of Florida program (1986-1991) were also described in Beckman et al., 1995. Field performance of more recent 'AP' (Attapulgus) selections out of this program (1991-present) has not been reported, although all provide significant improvements in various characteristics compared to current commercial cultivars that fall in the same ripening window (data not shown).

Fruit samples were collected at the University of Georgia Research Station located in Attapulgus, in the extreme southwest corner of Georgia. Fruit were picked at the 'shipping ripe' stage, i.e., as ground color changes from green to yellow (Delwiche and Baumgardner, 1983 and 1985), transported on trays in iced, coolers to the USDA-ARS laboratory at Byron, Ga. for testing, and stored overnight at 4°C.

The following day 10 peaches of each genotype were measured for fruit weight, ground color and firmness. Ground color was measured on the greenest area of the fruit using a Minolta CR-200 Chroma Meter (Minolta Corp., 101 Williams Dr., Ramsey, NJ 07446). Color measurements were made as L*, a*, and b* components. Firmness was measured as coefficient of restitution as described by Meredith et al., 1990. This non-destructive technique measures the ability of the fruit flesh to rebound after being dropped from a short height (typically 1 cm) onto an impact force sensor as an indirect measure of firmness. A typical curve showing the relationship between fruit firmness as measured with a penetrometer and coefficient of restitution is shown in Figure 1. Three determinations were made on one cheek of each fruit and averaged together. After initial measurements, fruit were placed in cold storage at 4°C for 5 days and transferred to a 20°C environment for 2 days after which measurements were repeated. Typical temperature and relative humidity regimes in 1995 were 4.0 ± 0.1°C and 83 ± 0.1 percent relative humidity during the 5 day cold storage period and 21.0 ± 0.5°C and 60.3 ± 3.8 percent relative humidity during the 2 day 'room temperature' storage period.

Following the final set of color and firmness measurements, fruit were destructively sampled for percent soluble solids (SS), pH and titratable acidity (TA). A slice (ca. 25 mm in diameter) was removed from a cheek of each fruit and squeezed to express juice directly onto a digital refractometer (Atago, Model PR-1, NSG Precision Cells, Inc. 195 G. Central Ave., Farmingdale, NY) for determination of SS. Titratable

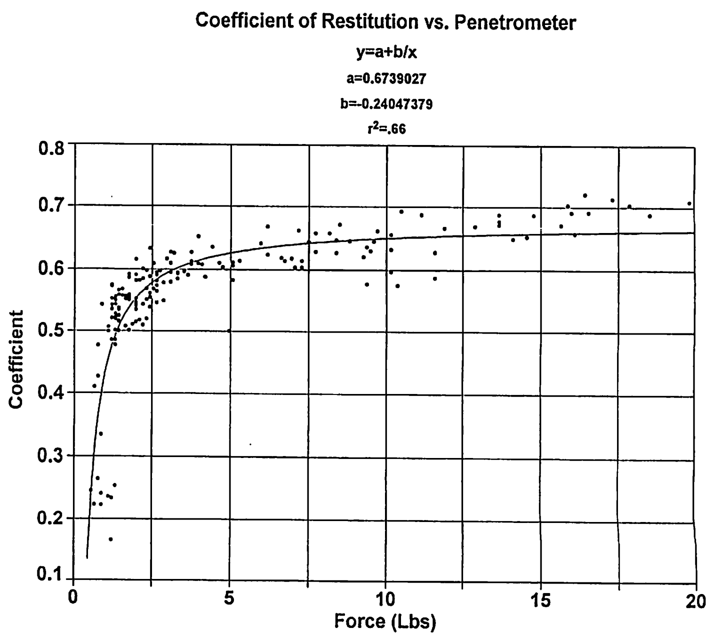

Figure 1. Data from 80 peaches (1 measurement per cheek, 3 coefficient of restitution determinations per measurement) showing the average coefficient of restitution vs. penetrometer force (McCormick Fruit Pressure Tester, Model FT327, fitted with 8 mm tip).

acidity was determined as follows. The 10 fruit sample of each cultivar was divided into 2 groups of 5 fruit each. A small sample of flesh (ca. 2 grams) was collected from each of the 5 fruit in each group and composited into one sample and the final weight adjusted to 10 grams. Fifty mL of distilled water were added and the sample pureed in a Waring blender. Pureed samples were stored at -10°C until analysis (Robertson et al., 1988). Finally, fruit were sliced in half and inspected for incidence of internal split pits. Color measurements were converted from L*, a*, and b* to L*, Hue angle and Chroma, per McGuire (1992), before analysis. Data were analyzed by the General Linear Models (GLM) program of the Statistical Analysis System for personal computers (SAS Institute, Inc., 1996). Mean separation was performed by LSD.

Results and Discussion

Evaluation of current commercial cultivars. Current standard cultivars varied considerably in average fruit size (Table 1). However, all fruit easily exceeded 90 grams (data not shown) which is a typical weight for a 57 mm diameter peach (2.25"), the smallest and most common size sold in this season. Cultivars also varied significantly in initial coefficient of restitution measurements. However, differences were small and all cultivars approached or exceeded values of 0.70 which, in our experience, correlates well with subjective field rating of 'adequate firmness' for shipping. Commercial recommendation (Kader and Mitchell, 1989) is for 9-10 lbf at harvest for early season fruit in California. This would correlate with a coefficient of restitution of ca. 0.65. Differences were much larger after storage, ranging from a drop of zero for 'Delta' to 25% for 'Flordacrest'. With the exception of 'Delta', which is a very slow to soften non-melting type, there was an apparent pattern of faster rate of softening in the earlier ripening fruit, which agrees with our field observations. Nevertheless, all fruit were judged to have sufficient firmness to survive gentle handling at time of purchase. However, Deshpande and Salunkhe (1964) characterized eating ripe or tree ripe fruit as having a firmness of ca. 3 lbf which correlates with a coefficient of restitution of ca. 0.58, higher than some varieties tested here.

As shown in Table 1, percent soluble solids varied considerably for these commercially available cultivars, but few approached the 12 to 16% reported for high quality, later season varieties (Robertson et al., 1990). With the exception of 'Delta', titratable acidity was considerably higher for all cultivars than the 0.5 to 0.8% reported for high quality, later season varieties (Robertson et al., 1990). The balance of the two factors as expressed by the ratio of soluble solids to titratable acidity was low for all cultivars except 'Delta'. Typically, high quality fruit would display a ratio of at least 15 (Robertson et al., 1990). In general, we would expect these cultivars to have been perceived by consumers as lacking in sweetness. The most likely taste perception would have been one of acidity.

'Flordaking' and 'June Gold' displayed the largest number of hidden internal split pits, with 'June Gold' being significantly higher than all other cultivars tested (Table 1). These estimates are conservative since no fruit with visible splits at the stem end were allowed in the sample. This resulted in many more fruit of 'Flordaking' and 'June Gold' being rejected during sample collection than other cultivars. Growers typically report up to 20% of harvested 'Flordaking' fruit being culled for visible splits (Howard Lawson, pers. comm.). Clearly, there is much room for improvement in the fruit quality of the cultivars currently utilized in this industry.

Ground color L* and Chroma values changed very little during storage (Table 2). However, the Hue Angle of all varieties tested shifted from yellow toward yellow-orange, consistent with the loss of green as the yellow ground color develops and the introduction of flecks of red blush in the background color. The ground color of 'White Robin', a white-fleshed cultivar, had a distinctly lower Chroma value than other varieties tested, i.e., it was less saturated and more grayish (or whitish) in appearance both before and after storage than all of the yellow-fleshed cultivars.

Evaluation of advanced selections. As part of this project, we also sampled advanced selections being developed in this program. In most cases these selections have been justified on the basis of subjective field evaluations which are heavily weighted on fruit crop load, size, firmness and, especially appearance factors such as fruit shape and red blush (Beckman et al., 1995). Those that ripened with 'Flordaking' are listed in Table 3. While competitive with 'Flordaking', none appeared to be markedly superior in postharvest characteristics and all were significantly smaller in size. SG91-5 may have been the most promising with its superior post-storage firmness, but it suffered from a relatively high number of split pits.

Table 1. Postharvest performance of commercial moderate-chill peach cultivars (1993-1995[z], Attapulgus, GA).

					Coefficient of restitution						
Cultivar	Type[y]	Chill[x]	Harvest date[w]	Wt (g)	Before storage	After storage	Change (%)	SS (%)	TA[v] (%)	SS/TA	Split pits (%)
Flordaking	M	400	125	158 a	0.68 c	0.52 c	-23 ab	10.6 b	1.00 c	10.6 b	15 b
Flordacrest	M	400	131	141 c	0.70 ab	0.53 c	-25 a	9.4 d	1.02 c	9.2 c	0 b
Texstar	M	550	139	125 d	0.68 bc	0.58 bc	-14 bc	9.8 cd	1.25 ab	7.9 d	10 b
June Gold	M	650	141	145 bc	0.69 abc	0.59 b	-14 bc	10.2 bc	1.02 c	10.0 bc	35 a
White Robin	M	500	142	125 d	0.71 a	0.62 b	-12 c	10.5 b	1.33 a	7.9 d	0 b
Delta	NM	550	150	156 ab	0.70 ab	0.70 a	+0 d	10.6 b	0.80 d	13.5 a	0 b
Juneprince	M	600	153	154 ab	0.71 a	0.65 ab	-8 cd	11.2 a	1.19 b	9.5 bc	5 b
LSD .05[u]	—	—	—	11	0.02	0.06	10	0.6	0.10	1.1	19

[z]SS, TA and split pits based on 1994-1995 data only.
[y]M = melting type flesh, NM = non-melting type flesh.
[x]Estimated chilling requirement, hours below 7°C.
[w]Julian date.
[v]As malic acid.
[u]Mean separation within columns by LSD; means within columns followed by the same letter not significantly different at $P \leq 0.05$.

Table 2. Postharvest ground color changes during storage of commercial moderate-chill peach cultivars (1993-1995, Attapulgus, GA).

					Ground color values[z]					
					Before storage			After storage		
Cultivar	Type[y]	Chill[x]	Harvest date[w]	Flesh color	L*	C*	h°	L*	C*	h°
Flordaking	M	400	125	Yellow	70.1 b	46.3 b	90.9 a	72.0 ab	48.9 ab	84.3 a
Flordacrest	M	400	131	Yellow	69.6 bc	47.3 b	82.6 bc	70.0 bc	50.2 a	76.2 cd
Texstar	M	550	139	Yellow	70.4 b	47.6 b	86.3 abc	70.8 bc	48.6 ab	82.5 ab
June Gold	M	650	141	Yellow	70.6 c	47.3 b	88.8 ab	71.5 b	47.5 b	84.8 a
White Robin	M	500	142	White	67.6 c	31.1 c	74.6 d	68.6 c	31.2 d	70.6 d
Delta	NM	550	150	Yellow	73.7 a	50.4 a	90.0 a	74.3 a	48.7 ab	83.9 ab
Juneprince	M	600	153	Yellow	67.4 c	46.7 b	80.9 cd	68.2 c	45.1 c	78.3 bc
LSD .05[u]	—	—	—	—	2.5	1.7	6.4	2.7	1.7	5.9

[z]Measured using a Minolta chroma meter CR-200 in CIELAB and converted to L* = lightness, C* = chroma and h° = hue angle (0° = red-purple, 90° = yellow, 180° = bluish-green) as described in McGuire, 1992. Instrument calibrated on white target CRA43, using C illuminant and d/0 illuminant/viewing geometry.
[y]M = melting type flesh, NM = non-melting type flesh.
[x]Estimated chilling requirement, hours below 7°C.
[w]Julian date.
[u]Mean separation within columns by LSD; means within columns followed by the same letter not significantly different at P ≤ 0.05.

Selections ripening with 'June Gold' are listed in Table 4. Again, all selections were competitive with 'June Gold' but none were significantly better based on postharvest characteristics.

Selections ripening with 'Juneprince' are listed in Table 5. Here 'Delta' stood out as a potentially superior alternative to 'Juneprince'. 'Delta' achieved similar size, which was large even for the season, exceeding 64 mm (2.5") on average, and had the best flavor balance of selections reported. Importantly, 'Delta' softened very little in storage due to its non-melting flesh. Indeed, it likely could have successfully gone through the storage protocol a second time. However, 'Delta' is pollen sterile (Johnson et al., 1994), and this will likely limit its potential to become a major commercial cultivar.

The chief advantages of this program's early melting type selections include significant improvements in fruit appearance factors (red blush and fruit shape), marked reductions in incidence of split pits, and incremental improvements in fruit firmness (Beckman et al., 1995). While all of these factors are important in influencing the consumer's initial purchase decision, with the exception of fruit firmness, they have little to do with those attributes that contribute to consumer eating satisfaction, i.e., taste, aroma and texture. This analysis indicates that few, if any, of the advanced melting type selections tested provide significant improvements in postharvest characteristics.

In 1995, we were able to fruit, for the first time, a number of advanced non-melting flesh selections out of the University of Florida program. Although not adapted for use in the South Georgia shipping industry due to their low chilling requirement, they nevertheless served as a first indication of what might be possible with this type of germplasm. Table 6 shows the overall performance for 5 of these non-melting selections (plus 'Delta') compared with 6 melting type selections and 6 standard commercial melting type cultivars. The trends are notable. Post-storage firmness is markedly improved in the non-melting materials which, on average, displayed less than half of the softening observed in melting type materials. Moreover, the non-melting materials displayed higher soluble solids and fewer split pits compared to current commercial melting type cultivars. Recent selections in this program have demonstrated that fruit size need not be sacrificed in non-melting germplasm.

The non-melting flesh trait can be capitalized on in either of two ways. The first possibility is that growers can harvest this type of peach at the usual 'shipping ripe' stage (not completely ripe) and simply benefit from its superior handling charac-

Table 3. Postharvest performance of commercial moderate-chill peach cultivars and new selections during 'Flordaking' season (1993-1995, Attapulgus, GA).

					Coefficient of restitution						
Cultivar	Type[y]	Chill[x]	Harvest date[w]	Wt (g)	Before storage	After storage	Change (%)	SS (%)	TA[v] (%)	SS/TA	Split pits (%)
SG90-4	M	450	124	125 c	0.69 a	0.49 b	-30 a	10.8 a	1.11 b	9. b	0 b
Flordaking	M	400	125	158 a	0.68 b	0.52 b	-23 ab	10.6 a	1.00 c	10.6 a	15 ab
SG90-6	M	375	126	124 c	0.70 a	0.54 ab	-24 ab	9.5 bc	1.18 a	8.0 d	0 b
Flordacrest	M	400	131	141 b	0.70 a	0.53 b	-25 ab	9.4 c	1.02 c	9.2 c	0 b
SG91-5	M	425	131	130 c	0.70 a	0.61 a	-13 b	10.0 b	1.05 bc	9.5 bc	25 a
LSD .05[u]	—	—	—	9	0.02	0.08	13	0.6	0.06	0.5	16

[z]SS, TA and split pits based on 1994-1995 data only.
[y]M = melting type flesh, NM = non-melting type flesh.
[x]Estimated chilling requirement, hours below 7°C.
[w]Julian date.
[v]As malic acid.
[u]Mean separation within columns by LSD; means within columns followed by the same letter not significantly different at P ≤ 0.05.

Table 4. Postharvest performance of moderate-chill commercial peach cultivars and selections during 'June Gold' season (1993-1995[z], Attapulgus, GA).

					Coefficient of restitution						
Cultivar	Type[y]	Chill[x]	Harvest date[w]	Wt (g)	Before storage	After storage	Change (%)	SS (%)	TA[v] (%)	SS/TA	Split pits (%)
Flordacrest	M	400	131	141 a	0.70 ab	0.53 b	-25 a	9.4 c	1.02 b	9.2 b	0 c
SG91-5	M	425	131	130 b	0.70 a	0.61 a	-13 b	10.0 ab	1.05 b	9.5 b	25 ab
Texstar	M	550	139	125 b	0.68 b	0.58 a	-14 b	9.8 bc	1.24 a	7.9 c	10 bc
June Gold	M	650	141	145 a	0.69 ab	0.59 a	-14 b	10.2 ab	1.02 b	10.0 a	35 a
White Robin	M	500	142	125 b	0.71 a	0.62 a	-12 b	10.5 a	1.33 a	7.9 c	0 c
LSD .05 [u]	—	—	—	9	0.02	0.04	6	0.6	0.09	0.4	20

[z]SS, TA and split pits based on 1994-1995 data only.
[y]M = melting type flesh, NM = non-melting type flesh.
[x]Estimated chilling requirement, hours below 7°C.
[w]Julian date.
[v]As malic acid.
[u]Mean separation within columns by LSD; means within columns followed by the same letter not significantly different at $P \leq 0.05$.

teristics. The second, and we believe more valuable, possibility is that growers could institute a 'tree-ripe' program by

recovering a premium price may be needed to offset the increased risk associated with this approach. Part of that reward

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POSTHARVEST CHARACTERISTICS AND CONSUMER ACCEPTANCE OF NON-MELTING PEACHES

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Abstract. **In 1997 and 1998, non-melting and melting clones of peach [*Prunus persica (L.)* Batsch.] from the University of Florida *Prunus* breeding program were compared for post-harvest quality characteristics including blush and ground color, flesh firmness, percent soluble solids, and acidity. Fruit were harvested and stored at 0°C for 14 days. After cold storage, fruit were analyzed immediately (1998), or held at 20°C for 3 days before postharvest quality analyses were conducted (1997). 'UFGold' (a non-melting flesh cultivar) was similar, or slightly superior, to 'Flordaprince' (a melting flesh cultivar) for blush and ground color, and acidity. Soluble solids were higher for 'UFGold' than for 'Flordaprince' both years. Non-melting flesh clones had much firmer flesh after storage than melting flesh clones. Consumer acceptance trials for the melting and non-melting clones were conducted at a local supermarket during 1997 and 1998. One-hundred (1997) or fifty (1998) consumers were surveyed over a two-day period. The non-melting flesh clones rated higher than the melting flesh clones for most consumer quality assessment characteristics including texture, appearance, and overall quality.**

Peaches grown for fresh consumption are harvested at the "firm ripe" stage of maturity to minimize bruising and maximize their postharvest life. Optimum harvest time is considered to be when fruit are advanced enough in their maturity to continue ripening and develop high flavor characteristics, yet firm enough to prevent bruising and premature softening during shipping and storage (Wells et al., 1989). Various maturity indices including ground color, red over-color and firmness have been used to determine harvest date for peach (Delwiche and Baumgardner, 1983; Rood, 1957; Wells et al., 1989). Unfortunately, in an attempt to minimize fruit losses during handling and storage, fresh market peaches are often harvested too immature to develop high flavor (Sherman et al., 1990). A major goal of the University of Florida *Prunus* breeding program is to develop non-melting flesh peaches for the fresh market with color, aroma, and taste typical of melting-flesh cultivars (Sherman et al., 1990). Preliminary research suggests that these new, non-melting flesh, cultivars have greater potential for cold storage and long-distance shipping than traditional melting flesh peaches (Brovelli et al., 1998; Robertson et al., 1992). The objective of this study was to compare postharvest quality characteristics and consumer acceptance of melting and non-melting flesh peaches grown for the fresh market.

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Materials and Methods

Postharvest study. In 1997 and 1998, 'Flordaprince' and 'UFGold' fruit were harvested from the teaching orchard on the University of Florida campus, Gainesville, Fla. In 1997, the fruit were stored for 14 days at 0°C followed by 3 days at 20°C before postharvest analyses were conducted. In 1998, fruit were stored for 5 days at 0°C followed by 3 days at 20°C. Fifteen fruits of each cultivar were used to determine firmness, soluble solids, titratable acidity, and ground and blush color. Ground and blush color were measured with a Minolta colorimeter. The "a" and "b" values were measured from the greenest and reddest area of each fruit and used to compute hue angle and chroma for ground and blush color, respectively. Firmness was measured with an Instron penetrometer by measuring the force required to insert a 11 mm diameter probe 8 mm into the flesh on opposite cheeks of each fruit. Fruit were then peeled, sliced and pureed in a Waring Blender for one minute and stored at -20°C until analyses for titratable acidity and soluble solids were conducted.

Consumer acceptance study. Consumer acceptance trials of melting and non-melting flesh peaches were conducted at a local supermarket during 1997 and 1998. In 1997, two ad-