Available online at www.sciencedirect.com
SCIENCE DIRECT
Postharvest Biology and Technology 39 (2006) 10–18
Postharvest Biology and Technology
www.elsevier.com/locate/postharvbio

Segregation of peach and nectarine (*Prunus persica* (L.) Batsch) cultivars according to their organoleptic characteristics

Carlos H. Crisosto[a,*], Gayle M. Crisosto[a], Gemma Echeverria[b], Jaume Puy[c]

[a] *Department of Plant Sciences, University of California, Davis, CA 95616, USA*[1]
[b] *Centre UdL-IRTA, Rovira Roure, 191, Lleida 25198, Spain*
[c] *Departament de Química, Rovira Roure, 191, Lleida 25198, Spain*

Received 4 March 2005; accepted 22 September 2005

Abstract

Cultivar segregation according to the sensory perception of their organoleptic characteristics was attempted by using trained panel data evaluated by principal component analysis of four sources per cultivar of 23 peach and 26 nectarine cultivars as a part of our program to develop minimum quality indexes. Fruit source significantly affected cultivar ripe soluble solids concentration (RSSC) and ripe titratable acidity (RTA), but it did not significantly affect sensory perception of peach or nectarine flavor intensity, sourness or aroma by the trained panel. For five out of the 49 cultivars tested, source played a role in perception of sweetness. In all of these cases when a source of a specific cultivar was not classified in the proposed organoleptic group it could be explained by the fruit having been harvested outside of the commercial physiological maturity (immature or over-mature) for that cultivar. The perception of the four sensory attributes (sweetness, sourness, peach or nectarine flavor intensity, peach or nectarine aroma intensity) was analyzed by using the three principal components, which accounted for 92 and 94% of the variation in the sensory attributes of the tested cultivars for peach and nectarine, respectively. Season did not significantly affect the classification of one cultivar that was evaluated during these two seasons. By plotting organoleptic characteristics in PC1 and PC2 (∼76%) for peach and nectarine, cultivars were segregated into groups (balanced, tart, sweet, peach or nectarine aroma and/or peach or nectarine flavor intensity) with similar sensory attributes; nectarines were classified into five groups and peaches into four groups. Based on this information, we recommend that cultivars should be classified in organoleptic groups and development of a minimum quality index should be attempted within each organoleptic group rather than proposing a generic minimum quality index based on the ripe soluble solids concentration (RSSC). This organoleptic cultivar classification will help to match ethnic preferences and enhance current promotion and marketing programs.

Keywords: Sensory attributes; PCA; Ripe fruit quality attributes; Minimum quality index

1. Introduction

In the last decade, peach and nectarine per capita consumption has remained the same or even decreased in the USA (Anon., 2004) and some European countries (Liverani et al., 2002; Hilaire and Mathieu, 2004). Consumer complaints for peaches center on lack of flavor and textural characteristics associated with ripening (Bruhn et al., 1991), in addition to chilling injury symptoms such as "off flavor", mealy texture and flesh browning (Von Mollendorff et al., 1992). At the same time, costs of production are increasing while prices are not. Postharvest handling practices with an emphasis on temperature management recommendations to avoid chilling injury have been proposed as part of the solution (Mitchell, 1987; Crisosto et al., 1999). Ripening protocols at the shipping and receiving end have been developed, promoted and established as an attempt to enhance

* Corresponding author. Tel.: +1 559 646 6596; fax: +1 559 646 6593.
E-mail address: carlos@uckac.edu (C.H. Crisosto).
[1] Located at Kearney Agricultural Center, 9240 S. Riverbend Avenue, Parlier, CA 93648, USA.

0925-5214/$ – see front matter © 2005 Elsevier B.V. All rights reserved.
doi:10.1016/j.postharvbio.2005.09.007

flavor or even give an added value to peaches and nectarines (Crisosto, 1997, 2000; Crisosto et al., 2004a). Other approaches to increase consumption have been taken by plant breeders, who are developing and introducing new peach and nectarine cultivars with different chemical characteristics than cultivars previously planted (Byrne, 2003). These recently released white or yellow flesh cultivars with low, medium or high acidity and/or high soluble solids concentration (SSC) (measured at harvest), more peach or nectarine flavor and/or aroma have the potential of being perceived as cultivars with different sensory attributes (Neri et al., 1996). Unfortunately, sensory classification of peach and nectarine cultivars based on the organoleptic perception of these characteristics by consumers has not been investigated. Another approach to increase consumption that is being pursued by several postharvest physiologists is the establishment of a generic single minimum quality index based on a level of SSC (Ravaglia et al., 1966; Kader, 1994; Testoni, 1995; Ventura et al., 2000; Hilaire, 2003). Following this generic SSC approach, agricultural engineering companies are introducing nondestructive sensors to segregate fruit based on SSC or other fruit quality attributes prior to and during packaging that will help to enforce any proposed minimum quality standard (Chen, 1996; Shmulevich, 2003). However, it is well accepted by postharvest physiologists, but not well documented for peaches and nectarines, that there are some commodities or situations in which titratable acidity, characteristic flavor, aroma, astringency and texture become as important as SSC in determining consumer acceptance. For example, the interaction between RSSC and ripe titratable acidity (RTA) has been reported for an early dark plum (Crisosto et al., 2004b) and RTA may also be involved in consumer acceptance for early season peach and nectarine cultivars with high acidity and/or low RSSC situations. It has been reported that RTA plays an important role in consumer acceptance for grapes (Nelson et al., 1973; Crisosto and Crisosto, 2002), cherries (Kappel et al., 1996; Crisosto et al., 2003b) and kiwifruit (Crisosto and Crisosto, 2001; Marsh et al., 2004). The establishment of a generic single quality index based on SSC (Neri et al., 1996; Crisosto, 2002; Crisosto et al., 2003a; Hilaire and Mathieu, 2004) may create more confusion in the market without contributing to the solution of the consumption problem. For this reason, we believe that it is important to segregate cultivars according to their most dominant organoleptic characteristic (i.e. sweetness, sourness, peach or nectarine flavor intensity, or peach or nectarine aroma) and then develop a reliable minimum quality index within each organoleptic group. As peaches and nectarines are currently reaching new domestic and overseas markets with diverse consumer ethnic groups (Liverani et al., 2002; Crisosto et al., 2003a), this proposed organoleptic classification may help to match fruit characteristics to consumers' specific characteristic requirements and enhance marketing and promotion activities.

Our sensory research program involved the following steps: verify the variability of sensory attributes in current peach and nectarine cultivars, segregate cultivars into organoleptic groups, describe the chemical attributes of each organoleptic group, propose a minimum quality index within each organoleptic group, and understand the relationship between ethnic preferences and these proposed organoleptic groups. In this work we reported information on the first two steps.

2. Materials and methods

2.1. Trained panel

Cultivar segregation studies focused on the organoleptic description of 23 peach and 26 nectarine cultivars from four sources per cultivar (Table 1) were carried out by a panel of nine (2003) or ten (2004) trained judges selected for their taste acuity (O'Mahony, 1986; Lawless and Heymann, 1998). The same sources of 'Sweet Dream' peaches were evaluated during these two seasons as an internal control for taste panel and/or environmental conditions. Yellow and white flesh peach and nectarine cultivars with diverse combinations of fruit quality attributes (low and high acidity, high soluble solids concentration (SSC) and high peach or nectarine aroma) originating from different breeding programs were selected for this study. Both years, training sessions were conducted to instruct the judges on measuring the perception of sweetness, sourness, peach or nectarine flavor intensity and peach or nectarine aroma intensity using references (O'Mahony, 1986). At each session, judges evaluated no more than a maximum of eight cultivar–source combinations for aroma and taste attributes. All testing was carried out at room temperature (20 °C) in individual booths illuminated with fluorescent lighting. Samples were presented in random order in 162.6 ml soufflé cups labeled with three digit random numbers. For each cultivar–source, fruit were harvested at the peak size and California Well-Mature for that cultivar, then held at 0 °C for approximately 7–10 days until ripened. Prior to testing, the fruit were ripened at 20 °C in a temperature-controlled room for 1–5 days until a subsample measured 8.8–12.3 N flesh firmness. On each fruit for tasting, a piece of skin ∼2 cm in diameter was removed from one cheek and the flesh firmness measured with a UC firmness tester (Western Industrial Supply, San Francisco, CA) equipped with an 8 mm tip. If the fruit was ripe (i.e. 8.8–13.2 N) it was labeled, the firmness recorded and used for taste. A sample for aroma consisted of one whole, ripened (selected by touch), unblemished fruit of the cultivar–source to be tested. A sample for taste consisted of two longitudinal slices cut from the stem end to the blossom end of the fruit on the cheek opposite the flesh firmness measurement of the cultivar–source to be tested. Judges scored a sample for each sensory attribute by circling a hatch mark placed at increments of 0.5 cm on a 10 cm horizontal line anchored 1 cm from both ends of the line by "none" and "more" (peach or nectarine aroma and flavor intensity) or "less" and "more"

Table 1
Means (*X*) and standard deviations (S.D.) of ripe soluble solids concentration (RSSC) and ripe titratable acidity (RTA) for peach and nectarine cultivars from four different sources per cultivar

	Cultivar code	Plant breeding program	RSSC[a]		RTA[a]	
			X	S.D.	*X*	S.D.
Peach cultivar						
Autumn Flame	AF	Doyle	12.0	1.7	0.52	0.05
Brittney Lane	BL	Zaiger	10.7	0.9	0.75	0.28
Country Sweet	CS	Zaiger	11.2	1.4	0.40	0.07
Diamond Princess	DP	Bradford	10.0	1.8	0.65	0.08
Elegant Lady	EL	Merrill	14.0	1.4	0.72	0.11
July Flame	JF	Burchell	11.1	0.6	0.70	0.06
Kaweah	KA	Zaiger	10.0	1.1	0.66	0.05
May Sweet	MS	Zaiger	11.5	0.9	0.42	0.07
O'Henry	OH	Merrill	12.4	0.3	0.82	0.05
Rich May	RM	Zaiger	10.6	0.4	0.79	0.06
Saturn	SA	Bailey	11.9	1.3	0.33	0.03
Snow Fire	SWF	Zaiger	13.6	1.0	0.30	0.03
Snow Kist	SK	Zaiger	11.4	1.3	0.36	0.10
Spring Snow	SPW	Zaiger	10.6	0.8	0.40	0.08
Sugar Lady	SL	Zaiger	11.7	1.2	0.30	0.05
Summer Sweet	SS	Zaiger	12.1	1.3	0.34	0.06
Summer Zee	SZ	Zaiger	11.1	0.4	0.61	0.06
Sunlit Snow	SUL	Zaiger	11.3	1.6	0.45	0.06
Super Rich	SR	Zaiger	11.8	1.0	0.78	0.12
Sweet Dream-2003	SD-03	Zaiger	12.2	1.1	0.31	0.03
Sweet Dream-2004	SD-04	Zaiger	11.3	0.6	0.24	0.04
Tra-Zee	TZ	Zaiger	11.5	2.0	0.69	0.07
White Lady	WL	Zaiger	12.5	2.6	0.25	0.03
Zee Lady	ZL	Zaiger	13.5	1.0	0.76	0.12
Nectarine cultivar						
Arctic Jay	AJY	Zaiger	12.9	3.1	0.57	0.10
Arctic Snow	ASOW	Zaiger	14.2	1.1	0.36	0.04
Arctic Star	ARS	Zaiger	10.8	1.7	0.63	0.20
Arctic Sweet	ASW	Zaiger	10.4	1.5	0.29	0.07
August Fire	AUF	Waldner	11.5	1.2	0.72	0.05
August Glo	AUG	Zaiger	12.0	0.8	0.71	0.08
Bright Pearl	BGP	Bradford	16.4	1.8	0.21	0.03
Diamond Bright	DBG	Bradford	11.5	2.6	1.07	0.22
Diamond Ray	DR	Bradford	10.5	0.7	0.83	0.09
Fire Pearl	FIP	Bradford	13.9	1.0	0.47	0.04
Fire Sweet	FRW	Bradford	13.1	1.4	0.24	0.01
Grand Pearl	GP	Bradford	14.2	1.8	0.29	0.04
Grand Sweet	GSW	Bradford	14.3	0.4	0.49	0.08
Honey Blaze	HB	Zaiger	13.6	1.9	0.56	0.09
Honey Kist	HK	Zaiger	13.1	2.9	0.53	0.11
Honey Royale	HR	Zaiger	14.9	1.3	0.44	0.05
Red Diamond	RED	Anderson	10.5	0.4	0.74	0.03
Royal Glo	RG	Zaiger	10.6	0.8	0.82	0.07
Ruby Diamond	RUD	Bradford	12.3	1.2	1.10	0.10
Ruby Pearl	RP	Bradford	12.7	2.3	0.31	0.04
Ruby Sweet	RSW	Bradford	12.5	1.5	0.46	0.07
September Free	SFR	USDA	13.7	1.6	0.77	0.12
Spring Bright	SPBG	Bradford	10.6	1.4	0.76	0.09
Summer Blush	SBL	Bradford	13.0	1.0	0.87	0.04
Summer Bright	SBG	Bradford	10.6	1.1	0.87	0.15
Zee Glo	ZG	Zaiger	13.2	1.2	0.96	0.09

[a] RSSC and RTA measured on ripe fruit (8.8 N) using a penetrometer with an 8 mm tip.

(sweetness and sourness). Labeled references at room temperature 20 °C were provided at each session: sweet less (SSC = 8.1 ± 0.1%, TA = 0.72%), sweet more (SSC = 16.0%, TA = 0.71 ± 0.02%), sour less (SSC = 11.0%, TA = 0.31%), sour more (SSC = 11.0%, TA = 1.19 ± 0.02%), flavor none (water), flavor more (100% Kern's peach nectar), aroma none (water), and aroma mid (100% Kern's peach nectar). Judges cleansed their nostrils between samples by inhaling and exhaling deeply two to three times. Judges cleansed their palates between samples and references with drinking water. After the aroma and taste evaluation, flesh firmness was measured on the aroma samples (2004) as previously described. Then, on all of the previously labeled fruit samples (aroma and taste), a longitudinal wedge was removed from the same area as the flesh firmness measurement, placed between two layers of cheesecloth and the juice expressed for subsequent soluble solids concentration (SSC) and titratable acidity (TA) measurements.

2.2. Data analysis

The relationship between cultivar–source and perception of sensory attributes by a trained panel and fruit chemical composition (SSC and TA) was calculated by using the SAS program. Cultivars were segregated into groups according to the average of their sources according to organoleptic characteristics by using the principal component analysis program (CAMO ASA, 1997). In five of the tested cultivars in which the source played a significant (p-value ≤ 0.05) role in the perception of sensory attributes, PCA was also carried out by source within each of these cultivars.

3. Results and discussion

Even though all of the sources within a cultivar had significantly different RTAs, and for most of the cultivars RSSC was significantly different between sources, most of the sources for a given cultivar did not deviate from the sensory attributes of that cultivar. For ‘Autumn Flame’, ‘Brittney Lane’, ‘May Sweet’, and ‘Sugar Lady’ peaches, RSSC was not related to their sources. Two of these cultivars (‘Brittney Lane’ and ‘May Sweet’) are early peaches that ripen during the last 2 weeks of May and their RSSCs have been historically between ∼9.5 and 10.5% with little variability between orchards (less than 1.0%). ‘May Sweet’ is a recent introduction so there is no historical data available for it. Thus, this small variability in RSSC can explain the lack of source significance for these cultivars. Within the cultivars tested, source had a significant effect on perception of sweetness for five cultivars, but source was not related to perception of peach or nectarine flavor intensity, aroma or sourness (Table 2). In all of the cultivars tested, source did not significantly affect flavor, aroma or sourness perception even though sources differed significantly in RTA within a given cultivar. It has been our experience over the last 10 years that

Table 2
Significance (p-values) of correlation between four sources each per cultivar of peach and nectarine cultivars and perception of sensory attributes by a trained panel and fruit chemical composition

Fruit	Cultivar	Sweetness	Sourness	Flavor	Aroma	RSSC	RTA
Peach	Autumn Flame	0.33	0.60	0.25	0.80	0.64	0.02
Peach	Brittney Lane	0.14	0.06	0.16	0.06	0.11	<0.0001
Peach	Country Sweet	0.50	0.49	0.58	0.29	0.0003	0.004
Peach	Elegant Lady	0.59	0.23	0.99	0.89	0.003	<0.0001
Peach	Kaweah	0.78	0.87	0.12	0.36	0.0003	0.01
Peach	May Sweet	0.24	0.17	0.17	0.77	0.49	0.0001
Peach	Saturn	0.93	0.78	0.78	0.95	<.0001	0.005
Peach	Spring Snow	0.004	0.14	0.06	0.17	<.0001	<0.0001
Peach	Sugar Lady	0.48	0.17	0.37	0.57	0.40	0.0002
Peach	Summer Sweet	0.49	0.64	0.20	0.76	0.003	<0.0001
Peach	Sunlit Snow	0.55	0.31	0.19	0.06	0.001	0.004
Peach	Super Rich	0.45	0.48	0.65	0.69	0.03	<0.0001
Peach	Sweet Dream	0.13	0.85	0.56	0.89	0.10	0.0003
Nectarine	Arctic Jay	0.002	0.06	0.41	0.57	<0.0001	0.35
Nectarine	Arctic Snow	0.45	0.58	0.34	0.24	<0.0001	<0.0001
Nectarine	Arctic Star	0.005	0.32	0.14	0.97	<0.0001	<0.0001
Nectarine	Arctic Sweet	0.05	0.19	0.41	0.86	<0.0001	<0.0001
Nectarine	Diamond Bright	0.30	0.74	0.29	0.90	0.0002	0.0001
Nectarine	Diamond Ray	0.96	0.52	0.36	0.38	0.10	0.03
Nectarine	Fire Pearl	0.35	0.86	0.10	0.15	0.01	0.003
Nectarine	Grand Pearl	0.21	0.61	0.40	0.39	0.0001	<0.0001
Nectarine	Honey Blaze	0.69	0.30	0.29	0.06	0.003	<0.0001
Nectarine	Honey Kist	0.04	0.38	0.14	0.45	<0.0001	<0.0001
Nectarine	Royal Glo	0.98	0.59	0.71	0.85	<0.0001	<0.0001
Nectarine	Ruby Pearl	0.67	0.34	0.62	0.75	<0.0001	0.008
Nectarine	Ruby Sweet	0.40	0.26	0.56	0.85	<0.0001	0.0002
Nectarine	September Free	0.36	0.31	0.69	0.50	0.06	<0.0001
Nectarine	Spring Bright	0.34	0.70	0.06	0.33	<0.0001	0.0001
Nectarine	Summer Blush	0.48	0.24	0.73	0.10	<0.0001	<0.0001
Nectarine	Summer Bright	0.54	0.76	0.61	0.40	0.11	<0.0001
Nectarine	Zee Glo	0.74	0.72	0.97	0.25	<0.0001	0.03

harvest titratable acidity (HTA) or RTA variability within a cultivar is less than for other fruit quality attributes such as RSSC, color, or firmness (Crisosto et al., 1997). This low RTA variability between sources for a given cultivar explains the fact that trained judges did not perceive sensory sourness differences between sources within a given cultivar. However, because there were large RTA differences between cultivars with low variability within the same cultivar, trained judges were able to segregate cultivars according to their perception of sourness.

For ‘Spring Snow’ peach and ‘Arctic Jay’, ‘Arctic Star’, ‘Arctic Sweet’, and ‘Honey Kist’ nectarines, source was significantly correlated to sweetness perception (p-value ≤ 0.05). Because source played a significant role in the perception of sweetness for this group of cultivars, we plotted PC1 and PC2 for these cultivar–source combinations to test if sources for the same cultivar were segregated into the same organoleptic group(s) (Figs. 1 and 2). For ‘Spring Snow’ peach, three sources were in the balanced group but fruit from source #1 (11.5% RSSC) were in the sweet group. For ‘Arctic Jay’ nectarine, sources #1, #2 and #3 were classified in the balanced group (10–12.7% RSSC), while fruit from source #4 (18% RSSC) were segregated into the sweet group. Fruit from ‘Arctic Star’ sources #1 (11.1% RSSC) and #4 (12.7% RSSC) were classified in the balanced group, while fruit from sources #2 (10.1% RSSC) and #3 (9.6% RSSC) were not classified in this group. For ‘Arctic Sweet’ nectarine, three sources (12.1, 10.9, 9.7% RSSC) were classified in the balanced group and the source with the lowest RSSC (9.1%) was not classified in this group. A different situation occurred with ‘Honey Kist’ in which the sources with RSSC between 10.9 and 12.8% were classified in the balanced group but the source with the highest RSSC (17.0%) and lowest RTA (0.38%) was classified in the sweet group. In our “in store” consumer tests, ‘Honey Kist’ consumer acceptance significantly increased from 72% (10–14% RSSC) to 88% for fruit with RSSC ≥14%. For these two RSSC ranges, the percentage of consumers that chose the dislike option was the same (∼2%). This suggests that consumers that chose the “neither like nor dislike” option for fruit with 10–14% RSSC changed to liking the fruit with RSSC ≥14% and therefore increasing the acceptance.

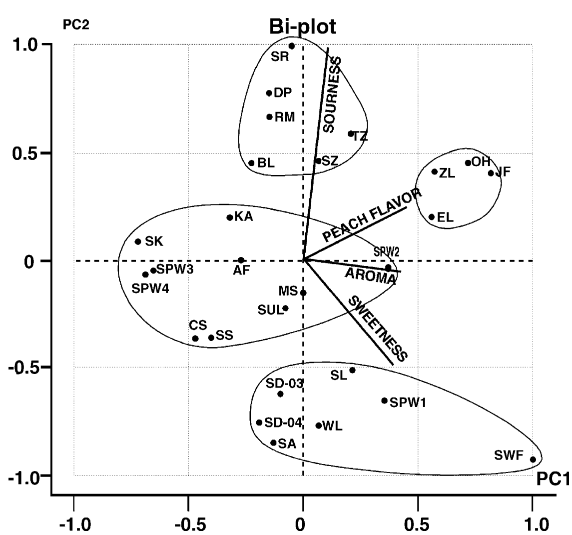

Fig. 1. Segregation of 23 peach cultivars originating from different breeding programs according to their organoleptic characteristics as perceived by a trained panel and determined by principal component analysis (PCA). PC1 (44%) is plotted on the X-axis and PC2 (33%) on the Y-axis with the vectors representing the loadings of sensory data along with the principal component scores.

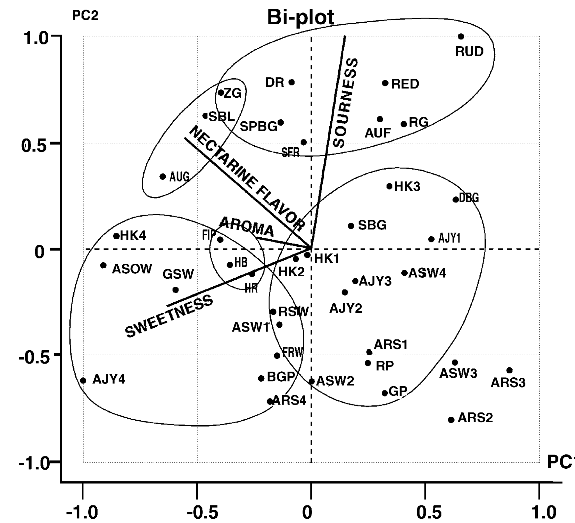

Fig. 2. Segregation of 26 nectarine cultivars originating from different breeding programs according to their organoleptic characteristics as perceived by a trained panel and determined by principal component analysis (PCA). PC1 (44%) is plotted on the X-axis and PC2 (31%) on the Y-axis with the vectors representing the loadings of sensory data along with the principal component scores.

3.1. Organoleptic segregation

Principal component analysis was used to segregate cultivars into different organoleptic groups. The perception of the four sensory attributes (sweetness, sourness, peach or nectarine flavor intensity, and peach or nectarine aroma) was reduced to three principal components, which accounted for 92% for peaches (Table 3) and 94% for nectarines (Table 4) of the variation in the sensory attributes of the tested cultivars. By plotting the 23 peach cultivars sensory attributes in the two most important principal components (PC1 and PC2), they were segregated into four groups named balanced, tart (sour), peach aroma/flavor, and sweet (Fig. 1) in which the cultivars in a given group had sensory attributes of the first two components clustered closely together, which accounted for 77% of this peach model (Table 3). PC1 accounted for 44% of the variability and it was positively loaded for peach flavor intensity, peach aroma and sweetness. In this model, sourness had little representation (component loading of 0.14). In contrast to PC1, PC2, which accounted for 33% of the variation, had high positive loading (0.88) for sourness and negative

Table 3
Component loadings for sensory attributes and component scores for 23 peach cultivars

Attribute	Component loadings			Cultivar	Component scores		
	PC1, λ = 44%	PC2, λ = 33%	PC3, λ = 15%		PC1	PC2	PC3
Sweetness	0.53	−0.43	−0.54	Brittney Lane	−0.72	0.94	0.46
Sourness	0.14	0.88	−0.17	Saturn	−0.43	−1.76	−0.42
Peach Flavor	0.62	0.21	−0.23	Country Sweet	−1.49	−0.76	−0.56
Peach Aroma	0.57	−0.05	0.79	Summer Sweet	−1.29	−0.76	−0.21
				Sweet Dream-2003	−0.32	−1.30	−0.36
				Kaweah	−1.02	0.40	−0.11
				Autumn Flame	−0.87	−0.03	0.35
				Super Rich	−0.27	2.05	0.06
				Rich May	−0.46	1.35	−0.20
				May Sweet	−0.02	−0.31	0.06
				Sunlit Snow	−0.26	−0.46	−0.25
				Snow Kist	−2.30	0.19	−1.09
				Sugar Lady	0.67	−1.07	0.58
				Elegant Lady	1.76	0.39	−0.73
				Snow Fire	3.17	−1.94	0.50
				White Lady	0.21	−1.60	−0.40
				Diamond Princess	−0.48	1.60	0.87
				Zee Lady	1.79	0.83	−0.81
				Sweet Dream-2004	−0.61	−1.57	−0.27
				July Flame	2.53	0.79	−0.28
				Summer Zee	0.21	0.93	−0.51
				O'Henry	2.25	0.90	−0.67
				Tra-Zee	0.64	1.20	−0.13
				Spring Snow-1	1.13	−1.36	0.70
				Spring Snow-2	1.17	−0.10	1.49
				Spring Snow-3	−2.08	−0.11	1.29
				Spring Snow-4	−2.17	−0.14	−0.35

loading for sweetness and the other attributes (Table 3). Cultivars plotted near the vectors representing the sensory loading data for peach flavor were classified in the peach flavor group. Only 'Spring Snow'-2 was classified in the aroma group. Cultivars plotted in between all four sensory vectors were classified in the balanced group. Cultivars plotted near either the sweetness or sourness vectors were classified in the sweet and tart groups, respectively. 'O'Henry', 'July Flame', 'Elegant Lady' and 'Zee Lady' were classified in the peach flavor group. 'Kaweah', 'Autumn Flame', 'Country Sweet', 'Spring Snow'-2, 'Spring Snow'-3, 'Spring Snow'-4, 'Summer Sweet', 'May Sweet', 'Snow Kist', and 'Sunlit Snow' peaches were classified in the balanced group. 'Snow Fire', 'White Lady', 'Sweet Dream'-2003, 'Sweet Dream'-2004, 'Saturn', 'Sugar Lady' and 'Spring Snow'-1 were classified in the sweet group. 'Brittney Lane', 'Diamond Princess', 'Rich May', 'Super Rich', 'Summer Zee', and 'Tra-Zee' were classified in the tart group.

For nectarines, judges' perception of the fruit sensory attributes (sweetness, sourness, nectarine flavor intensity and nectarine aroma) were represented by PC1 = 44%, PC2 = 31% and PC3 = 24%. Using PC1 and PC2 plotting analysis, which accounts for 75% of this model (Table 4), the 26 nectarine cultivars were segregated into five groups (balanced, sweet, tart (sour), nectarine flavor, nectarine aroma) in which the cultivars in a given group had sensory attributes clustered closely together (Fig. 2). PC1 accounted for 44% of the variability and it was negatively loaded for nectarine flavor intensity, aroma and sweetness, and positively loaded for sourness. PC2, which accounted for 31% of the variation included cultivars that contrast to PC1 with high positive loading for sourness, nectarine flavor intensity, and aroma and negative loading for sweetness (Table 4). 'Honey Kist'-1, 'Honey Kist'-2, 'Honey Kist'-3, 'Diamond Bright', 'Summer Bright', 'Arctic Star'-1, 'Arctic Jay'-1, 'Arctic Jay'-2, 'Arctic Jay'-3, 'Arctic Sweet'-1, 'Arctic Sweet'-2, 'Arctic Sweet'-4, 'Grand Pearl', 'Ruby Pearl', and 'Ruby Sweet' nectarines were classified in the balanced group. 'Arctic Sweet'-3, 'Arctic Star'-2, 'Arctic Star'-3 were not segregated into any of these groups but were near the balanced group. 'Ruby Diamond', 'Red Diamond', 'Diamond Ray', 'Royal Glo', 'Spring Bright', 'August Fire', 'September Free' and 'Zee Glo' were classified in the tart group. 'Arctic Snow', 'Arctic Star'-4, 'Arctic Jay'-4, 'Fire Sweet', 'Honey Kist'-4, 'Bright Pearl', 'Grand Sweet', 'Arctic Sweet'-1, 'Fire Pearl', 'Ruby Sweet', 'Honey Blaze', and 'Honey Royale' were classified in the sweet group. 'August Glo', 'Summer Blush', and 'Zee Glo' were classified in the nectarine flavor group. Within this group of cultivars, 'Fire Pearl', 'Honey Blaze' and 'Honey Royale' were cultivars classified in the nectarine aroma group.

Correlation coefficients between fruit chemical composition and perception of sensory attributes were significant and similar for peaches and nectarines (Table 5). For cultivars

Table 4
Component loadings for sensory attributes and component scores for 26 nectarine cultivars

Attribute	Component loadings		
	PC1, λ = 44%	PC2, λ = 31%	PC3, λ = 24%
Sweetness	−0.72	−0.22	−0.16
Sourness	0.16	0.87	0.02
Nectarine Flavor	−0.63	0.44	−0.22
Nectarine Aroma	−0.26	0.05	0.96

Cultivar	Component scores		
	PC1	PC2	PC3
Diamond Bright	1.83	0.52	−1.30
Honey Blaze	−1.04	−0.16	−0.34
Ruby Sweet	−0.48	−0.66	−0.60
Ruby Pearl	0.71	−1.15	0.34
Grand Pearl	0.92	−1.48	−1.70
Summer Bright	0.51	0.25	1.09
Royal Glo	1.18	1.29	0.32
Spring Bright	−0.39	1.32	0.52
Diamond Ray	−0.24	1.71	−1.25
Zee Glo	−1.14	1.62	0.77
August Glo	−1.89	0.76	0.08
Summer Blush	−1.35	1.37	−0.65
Arctic Snow	−2.64	−0.16	−0.18
September Free	−0.12	1.10	−0.73
Fire Pearl	−1.16	0.09	0.32
Grand Sweet	−1.72	−0.41	−2.14
Ruby Diamond	1.92	2.20	0.02
Bright Pearl	−0.63	−1.31	−1.00
Honey Royale	−0.76	−0.25	−1.18
Red Diamond	0.93	1.71	0.29
Fire Sweet	−0.43	−1.08	−1.11
August Fire	0.88	1.34	−0.71
Arctic Star-1	0.73	−1.06	−0.79
Arctic Star-2	1.81	−1.76	0.49
Arctic Star-3	2.52	−1.25	0.23
Arctic Star-4	−0.53	−1.53	−0.96
Arctic Jay-1	1.52	0.08	0.20
Arctic Jay-2	0.43	−0.44	1.75
Arctic Jay-3	0.56	−0.31	1.27
Arctic Jay-4	−2.91	−1.35	2.01
Arctic Sweet-1	−0.41	−0.76	0.76
Arctic Sweet-2	0.00	−1.34	0.08
Arctic Sweet-3	1.83	−1.16	1.04
Arctic Sweet-4	1.19	−0.25	1.41
Honey Kist-1	−0.06	−0.02	−0.53
Honey Kist-2	−0.20	−0.09	0.33
Honey Kist-3	1.00	0.65	−0.09
Honey Kist-4	−2.49	0.15	1.55

picked above their physiological maturity, RSSC had a higher correlation with sweetness, peach or nectarine flavor intensity, and aroma perception than RSSC/RTA. The fact that only ∼40% of the relationship between RSSC and sweetness perception is controlled by RSSC demonstrates that other quality attribute factors such as RTA, flavor and aroma are also involved in the perception of sweetness. A similar relationship has been reported previously in mangos (Malundo et al., 2001). RTA had a low correlation with sweetness but it had a significant and strong correlation (∼80%) with perception of sourness and was equally important as RSSC in perception of flavor (∼40%).

Table 5
Correlation coefficients (r) between ripe fruit chemical attributes and sensory attributes as perceived by a trained panel for 23 peach and 26 nectarine cultivars

	Sweetness	Sourness	Flavor intensity	Aroma
Peach RSSC	0.68***	NS	0.52**	NS
Peach RTA	NS	0.90***	0.50**	NS
Peach RSSC/RTA	0.47**	−0.86***	NS	NS
Nectarine RSSC	0.65***	NS	NS	NS
Nectarine RTA	−0.48**	0.86***	NS	NS
Nectarine RSSC/RTA	0.45**	−0.76***	NS	NS

** Significant at 1% level.
*** Significant at 0.1% level.

Because season did not affect organoleptic classification and fruit source only affected five out of 49 cultivar organoleptic classifications (all five of these cultivars had RSSC below or higher than their normal maturity/quality range) this proposed organoleptic group classification should be attempted. In order to create reliable organoleptic cultivar groups, the cultivar's potential quality attributes should be defined and RSSC or other quality attribute limits within each group should be established. Several techniques such as crop load adjustments, irrigation and others can be used to modify SSC but each cultivar has a limited SSC and/or TA range

(Crisosto et al., 1997). Our recent “in store” consumer tests carried out using ‘Honey Kist’, a low acid, yellow flesh nectarine (balanced group), ‘Elegant Lady’, a high acid, yellow flesh peach (peach flavor group), and ‘Spring Bright’, a high acid, yellow flesh peach (tart group) indicated that these cultivars have high consumer acceptance when fruit are above specific RSSC levels regardless of acidity or the proposed organoleptic group.

According to these results, we recommend that cultivars should be classified in organoleptic groups and development of a minimum quality index should be attempted within each organoleptic group rather than proposing a generic minimum quality index based on RSSC. This organoleptic cultivar classification will help to match ethnic preferences and enhance the current promotion and marketing programs. Future work should be pursued to describe the chemical attribute requirements for each organoleptic group to propose a minimum quality index. Furthermore, representative cultivars from each organoleptic group could be used to describe biochemical compounds related to the perception of their sensory attributes. After identification of these compounds, a candidate gene approach can be used to develop marker(s) to establish an early breeding (seedling) program screening for high quality fruit. After that, the relationship between trained panel data and consumer acceptance with an emphasis on ethnic preferences for these proposed organoleptic groups should be investigated.

Acknowledgements

The California Department of Food and Agriculture (CDFA) and the California Agricultural Technology Institute, California State University, Fresno provided economic support for this work.

References

Anon., 2004. Fruit and Tree Nuts: Situation and Outlook Yearbook, TFS-271. United States Department of Agriculture, Economic Research Service.

Bruhn, C.M., Feldman, N., Garlitz, C., Harwood, J., Ivans, E., Marshall, M., Riley, A., Thurber, D., Williamson, M., 1991. Consumer perceptions of quality: apricots, cantaloupes, peaches, pears, strawberries, and tomatoes. J. Food Qual. 14, 187–195.

Byrne, D., 2003. Breeding peaches and nectarines for mild-winter climate areas: state of the art and future directions. In: Marra, F., Sottile, F. (Eds.), Proceedings of the First Mediterranean Peach Symposium. Agrigento, Italy, September 10, pp. 102–109.

CAMO ASA, 1997. Unscrambler Users Guide, ver. 6.11a. Programme Package for Multivariate Calibration, Trondheim, Norway.

Chen, P., 1996. Quality evaluation technology for agricultural products. In: Proceedings of the International Conference on Agriculture Machinery Engineering, vol. 1, Seoul, Korea, November 12–15, pp. 171–204.

Crisosto, C.H., 1997. Stone fruit ripening protocol for receivers. 97/101, slide set with cassette tape. Division of Agriculture and Natural Resources.

Crisosto, C.H., 2000. Optimum procedures for ripening stone fruit. Management of Fruit Ripening. Postharvest Horticulture Series No. 9, April.

Crisosto, C.H., 2002. How do we increase peach consumption? Acta Hort. 592, 601–605.

Crisosto, C.H., Crisosto, G.M., 2001. Understanding consumer acceptance of early harvested ‘Hayward’ kiwifruit. Postharvest Biol. Technol. 22, 205–213.

Crisosto, C.H., Crisosto, G.M., 2002. Understanding American and Chinese consumer acceptance of ‘Redglobe’ table grapes. Postharvest Biol. Technol. 24, 155–162.

Crisosto, C.H., Johnson, R.S., Day, K.R., DeJong, T., 1997. Orchard factors affecting postharvest stone fruit quality. HortScience 32 (5), 820–823.

Crisosto, C.H., Mitchell, F.G., Ju, Z., 1999. Susceptibility to chilling injury of peach, nectarine, and plum cultivars grown in California. HortScience 34, 1116–1118.

Crisosto, C.H., Crisosto, G., Bowerman, E., 2003a. Searching for consumer satisfaction: new trends in the California peach industry. In: Marra, F., Sottile, F. (Eds.), Proceedings of the First Mediterranean Peach Symposium. Agrigento, Italy, September 10, pp. 113–118.

Crisosto, C.H., Crisosto, G.M., Metheney, P., 2003b. Consumer acceptance of ‘Brooks’ and ‘Bing’ cherries is mainly dependent on fruit SSC and visual skin color. Postharvest Biol. Technol. 28, 159–167.

Crisosto, C.H., Garner, D., Andris, H.L., Day, K.R., 2004a. Controlled delayed cooling extends peach market life. HortTechnology 14, 99–104.

Crisosto, C.H., Garner, D., Crisosto, G.M., Bowerman, E., 2004b. Increasing ‘Blackamber’ plum (*Prunus salicina* Lindell) consumer acceptance. Postharvest Biol. Technol. 34, 237–244.

Hilaire, C., 2003. The peach industry in France: state of art, research and development. In: Marra, F., Sottile, F. (Eds.), Proceedings of the First Mediterranean Peach Symposium. Agrigento, Italy, September 10, pp. 27–34.

Hilaire, C., Mathieu, V., 2004. Le Point sur la qualite gustative des peches et nectarines. Infos-Ctifl 201, 27–31.

Kader, A.A., 1994. Fruit maturity, ripening, and quality relationships. Perishable Handling Newslett. 80, 2.

Kappel, F., Fisher-Fleming, B., Hogue, E., 1996. Fruit characteristics and sensory attributes of an ideal sweet cherry. HortScience 31, 443–446.

Lawless, H.T., Heymann, H., 1998. Sensory Evaluation of Food: Principles and Practices. Food Science Texts Series. Chapman & Hall, New York, 827 pp.

Liverani, A., Giovannini, D., Brandi, F., 2002. Increasing fruit quality of peaches and nectarines: the main goals of ISF-FO (Italy). Acta Hort. 592, 507–514.

Malundo, T.M.M., Shewfelt, R.L., Ware, G.O., Baldwin, E.A., 2001. Sugars and acids influence flavor properties of mango (*Mangifera indica*). J. Am. Soc. Hort. Sci. 126, 115–121.

Marsh, K., Attanayake, S., Walker, S., Gunson, A., Boldingh, H., Macrae, E., 2004. Acidity and taste in kiwifruit. Postharvest Biol. Technol. 332, 159–168.

Mitchell, F.G., 1987. Influence of cooling and temperature maintenance on the quality of California grown stone fruit. Rev. Int. Froid. 10, 77–81.

Nelson, K.E., Schutz, H.G., Ahmedullah, M., McPherson, J., 1973. Flavor preferences of supermarket customers for ‘Thompson Seedless’ grapes. Am. J. Enol. Viticult. 24, 31–40.

Neri, F., Vassalli, P., Brigati, S., 1996. Valutazione organolettica di alcune cultivar di pesche e nettarine. Rivista di Frutticoltura 7/8, 57–63.

O’Mahony, M., 1986. Sensory Evaluation of Food. Marcel Dekker, Inc., New York.

Ravaglia, G., Sansavini, S., Ventura, M., Tabanelli, D., 1966. Indici di maturazione e miglioramneto qualitative delle pesche. Frutticoltura 3, 61–66.

Shmulevich, I., 2003. Nondestructive texture assessment of fruits and vegetables. Acta Hort. (ISHS) 599, 289–296.

Testoni, A., 1995. Momento di raccolta, qualità, condizionamento e confezionamento delle pesche. In: Proceedings of the Symposium La peschicoltura Veronese alle soglie del 2000, Verona, February 25, pp. 327–354.
Ventura, M., Sama, A., Minguzzi, A., Lazoni, S., Sansavini, S., 2000. Ottimizzazione del carico di frutti per migliorare la produzione e la qualità delle nettarine 'Supercrimson' e 'Venus'. In: Sansavini, S. (Ed.), Per una nuova peschicoltura: produzione, orrganizzazione, mercato. XXIV Convengo Peschicolo, Cesena, Febbraio 24–25, pp. 173–176.
Von Mollendorff, L.J., Jacobs, G., de Villiers, O.T., 1992. Cold storage influences internal characteristics of nectarines during ripening. HortScience 27, 1295–1297.